HABITAT USE, MOVEMENTS, MIGRATION PATTERNS, AND SURVIVAL RATES OF SUBADULT BALD EAGLES IN NORTH FLORIDA

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1992

ACKNOWLEDGMENTS

Many people contributed to the success of this research and to all of them I am grateful. I especially thank my graduate advisor, Dr. Michael W. Collopy. Mike rescued me from South Florida in 1985 and gave me an interesting and challenging opportunity to study bald eagles. He persuaded me to go back to graduate school for a PhD, recommended me for a CEA position, and has made many contributions thoughout this study. I also thank my committee members, Drs. Jack Kaufman, Franklin Percival, Joe Schaefer, and Mel Sunquist, for their contributions to this study and for reviews of this dissertation.

Financial support was provided by the Nongame Wildlife Program of the Florida Game and Fresh Water Fish Commission from fall 1987 to fall 1991. Radio-tracking equipment and initial work in spring 1987 was funded by the International Association of Fish and Wildlife Agencies and the Miller Brewing Company. The Cooperative Research Units Center, USFWS, provided funds for my CEA position with the Florida Cooperative Fish and Wildlife Research Unit.

Research assistants Myra Noss and Rick Sullivan spent numerous hours assisting with boat surveys. Research assistants Carolyn Sekerak and Linda Waite were invaluable in radio-tracking, banding, and data entry. Carolyn Sekerak also spent many hours collecting fledgling behavior data. I also thank the many volunteers who assisted with banding eagles. Dave Buehler shared his expertise in attaching radio-transmitters. Tree climbers Tony Steffer, Wayne Norton, and Craig Koppie made this study possible by retrieving nestling eagles from nests in very tall trees for banding and radio-tagging. Pilots Steve Schwikert and

Tom Campbell skillfully and safely flew aerial surveys and telemetry flights. Dr. John Smallwood conducted aerial nest surveys and banded nestlings in Ocala National Forest in 1989. Laura Cochran, Ocala N.F., conducted aerial nest surveys in Ocala National Forest in 1990 and 1991. Thanks also go to the many landowners who graciously granted access to eagle nests on their property. Many individuals reported sightings of marked bald eagles from this study outside of Florida--to all of them I am grateful. I especially thank Dave Buehler, Jim Fraser, Charlie Todd, Russ Treadwell, Peter Nye, and Mark King for their efforts in locating eagles on the Chesapeake Bay, in Maine, and in New York.

Steve Nesbitt, FGFWFC, offered advice on various phases of this study. Jim Weimer, Florida DNR, provided water level data for Alachua Lake and assistance at nests on Paynes Prairie State Preserve. The Office of Environmental Services, FGFWFC, provided the Landsat satellite imagery data and the Alachua County Department of Information Services provided a digitized data file of roads in Alachua County. The Florida Cooperative Fish and Wildlife Research Unit provided access to computer equipment and John Richardson and Leonard Pearlstine provided expertise for the analyses involving a geographic information system. Joann Boyko, Robert Coney, Monica Lindberg, Stan Ainsworth, Harry Buck, and Woody Christie of the University of Florida kept the paperwork under control.

Thanks to Cyndi, Brian, Nolls, Peter, Ruthe, Jeff, Tim, Cathy, Kathleen, Steve, and others for the welcome diversions of canoeing, the Hipp, and Risk. Finally, I especially thank John Wood for his support during my graduate career and his help on all aspects of this study.

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HABITAT USE, MOVEMENTS, MIGRATION PATTERNS, AND SURVIVAL RATES OF SUBADULT BALD EAGLES IN NORTH FLORIDA

By

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May 1992

Chairman: Michael W. Collopy
Major Department: Forest Resources and Conservation (Wildlife and Range Sciences)

The state of Florida supports over half of the breeding population of bald eagles (Haliaeetus leucocephalus leucocephalus) in the southeastern United States; this represents a significant resource for the Southeast and for Florida. Currently, primary management emphasis and protection is focused on bald eagle nest sites. No habitat protection or management activities are aimed at foraging, roosting or loafing areas for subadult eagles. In fact, habitats and habitat characteristics important to subadults have not been quantified. In this study, we examined various aspects of eagle biology that might be pertinent to survival or management of the Florida subadult eagle population. Specifically, using radio telemetry, we examined post-fledging habitat needs, factors affecting timing of migration, local movements, habitat use, and survival in north-central Florida from spring 1987 through spring 1991.

Fledgling eagles (birds prior to their initial migration) remained dependent on adults and remained within 4 km of the natal nest until they initiated migration (approximately 7

weeks post-fledging). It was determined that habitat protection within the 229 m primary protection zone used in Florida was not sufficient to meet the habitat needs of fledgling eagles and that the protection period should extend until fledglings initiate migration in the summer. Timing of migration for fledgling and 1- to 4-year-old eagles appeared to be correlated more with prey availability than with temperature, although both factors appear to affect migration.

Locations of radio-tagged eagles outside of Florida ranged from South Carolina to Prince Edward Island, Canada. Data suggest that eagles are philopatric to summering areas, which emphasizes the need for protection of significant summering areas. Known and assumed mortality occurred primarily during migration in northern states. The 1 1/2 year age class had the lowest survival. Survival was significantly lower for eagles fledged from 1-chick nests and for the younger chick in 2-chick nests. The minimum survival rate through 4 1/2 years of age was 50% and did not vary by sex.

After subadults returned to the north-central Florida study area in the fall, individuals continued to use the same general areas each year. Temporally and locally abundant food sources resulted in temporary small concentrations of eagles. Certain portions of the study area were used consistently each year by large numbers of eagles. Subadult eagles were not distributed randomly over the study area. Logistic regression analyses revealed that eagles tended to be located close to large water bodies and eagle nests, were frequently in cypress and marsh habitats, and avoided main roads and developed areas. Immature eagles (1-year olds) tended to be located closer to eagle nests than 2- to 4-year-olds. Thus, management for subadult populations must include these heavily used concentration areas that supply the habitat features preferred by subadults. Survival of subadults may be affected if a highly used area becomes unsuitable.

CHAPTER 1

STUDY OVERVIEW

Introduction

To fully understand the population dynamics of a species, all aspects of the life history must be examined and incorporated into deterministic or stochastic population models (Young 1968, Grier 1980). For many avian species, however, the period from fledging or independence to breeding is the least well understood. Similarly, little is known about seasonal movements, habitat requirements, or survivorship of the various age classes in subadult bald eagle (Haliaeetus leucocephalus) populations. In a population modeling study, Grier (1980) determined that survival rates were the most important factor affecting growth of long-lived, slow-breeding bird populations such as the bald eagle. In fact, eagle populations were twice as sensitive to changes in survival compared to fecundity (Grier 1980). Consequently, it is important to document survival rates for all age classes and to examine factors that might affect survival.

Previous studies in Florida addressed nesting habitat requirements (McEwan and Hirth 1979, Wood et al. 1989). Studies throughout the United States have examined eagle nesting ecology, in particular documenting fecundity. In winter concentration areas, various aspects of wintering habitat and ecology also have been addressed. Wintering habitats used by subadults had not been studied in an area such as Florida where eagles do not form large winter concentrations and where environmental factors, such as climate, are extremely different from temperate regions.

Bald eagles in Florida are at the extreme southern end of the range for the species and exhibit some life history characteristics that are distinct from more northern populations. Most notably, they breed in the winter and migrate north in the summer. Consequently, wintering areas for large numbers of nonbreeding and subadult eagles overlap with breeding areas.

Florida supports over half of the breeding population of bald eagles (H. l. leucocephalus) in the southeastern United States (Wood et al. 1990) with 601 known breeding pairs in 1991 (S. Nesbitt, pers. commun.). Consequently, Florida eagles represent an important part of the total southeastern population. Understanding the dynamics of Florida's eagle population, therefore, is necessary in understanding that of the southeastern population. In addition, studies on a large, stable population should yield results generally more applicable to other eagle populations than do studies on small, relict, or reestablished populations.

Currently, primary management emphasis and protection are focused on active bald eagle nest sites (U.S. Fish and Wildlife Service 1987), because it has been recognized that disturbance at nest sites can decrease productivity. Increasing productivity is not an effective management strategy, however, if immatures subsequently do not survive due to lack of adequate foraging, roosting, and loafing areas. At this time in Florida, there are no habitat protection measures aimed at foraging or roosting habitats that are important to nonbreeding subadults, or to breeding adults. Furthermore, habitats and habitat characteristics important to the non-breeding eagle population have not been identified.

In summary, very little is known about subadult eagle populations, particularly in an area such as Florida where large winter concentrations do not occur. In this study, I examined various aspects of eagle biology that might be pertinent to survival or management for the non-breeding segment of Florida's eagle population. Specifically, I characterized migration patterns, movements, habitat use, and survival rates of subadult bald eagles to 4 1/2

years of age in north-central Florida to provide data for effective management of this segment of the eagle population. Objectives for each segment of the study are enumerated in the pertinent chapter.

Study Area

Research focused on eagles found in the AMC study area comprising southern Alachua, northern Marion, western Putnam and eastern Levy counties, south of Gainesville, Florida (Figure 1-1). This area contains 340 bodies of open water ranging from 0.4 ha to 2,702 ha (mean = 12.6 ha) in size and numerous marshes and wet prairies (see Hartman 1978; also classified as palustrine persistent emergent wetland by Cowardin et al. 1979). Habitat availability was identified on the study area from a Landsat satellite image (courtesy of the Office of Environmental Services, Florida Game and Fresh Water Fish Commission). The 14 habitat types on the image were condensed into the 8 habitat classes (Table 1-1) considered in this study. Hartman (1978) described these Florida habitats.

Four large lakes occur on the study area that are used extensively by bald eagles. Newnan's Lake, located on the eastern edge of Gainesville, is a hyper-eutrophic lake of 2,433 ha (Shannon and Brezonik 1972) with a mean depth of 1.5 m (maximum = 4.0 m). Lake Lochloosa is a 2,235 ha meso-eutrophic lake about 20 km southeast of Gainesville with a mean depth of 2.9 m. Orange Lake is a 3,324 ha meso-eutrophic lake with a mean water depth of 1.8 m (maximum = 3.0 m) located about 20 km south of Gainesville. These 3 lakes have control structures that regulate water depth. They are rimmed primarily with baldcypress (Taxodium distichum) and hardwoods. Extensive areas of pine (Pinus spp.) forests surround Newnans and Lochloosa; Orange Lake is surrounded by pine forests and improved pasture. Lake Wauberg is a 101 ha eutrophic lake 11 km south of Gainesville;

mean depth is 3.8 m (maximum = 5.2 m). It is surrounded primarily with hardwoods, cypress, and sweet gum (Liquidambar styraciflua) swamp.

The secondary study area included Ocala National Forest and private lands on the east side of Lake George. This area also contains numerous lakes and wet prairies. The major water body, Lake George, is located on the St. Johns River system and is surrounded by bald cypress, hardwoods, and pine forests. The lands surrounding Lake George are used primarily for timber production.

Study Organization

The results and conclusions from this study are organized into 5 chapters. Chapter 2 examines post-fledging movements and habitat use. Timing of initial migration is related to various climatic factors, sibling aggression, and food availability. The post-fledging period begins when young fledge and ends when they leave the nest area to initiate migration.

Migration data are summarized in chapter 3. This chapter relates timing of migration to various climatic factors and prey availability. I also examine speed and distance of migratory movements and discuss out-of-state locations for 1- to 4-year-old eagles.

In chapter 4, I present movement and habitat use data for subadult eagles that have returned to the Florida study area and examine these data with respect to sex and age differences. I also address several human disturbance factors that may relate to movements and habitat use.

Chapter 5 examines survival rates of 1 to 4 year old eagles and contrasts survival in 3 eagle populations in relation to migratory patterns. I also discuss survival in relation to sex, timing of nesting, number of chicks, hatch order, and dispersal age. In chapter 6, I synthesize and discuss findings from all aspects of the study.

Table 1-1. Habitat types identified from a Landsat image and amount of each available on the study area in north-central Florida.

Habitat	Description	Hectares	Percent of study area
PINE	Pinewoods and mixed pine/hardwoods	36,723	26.9
	Sandhill	840	0.6
HDWD	Hardwoods (hammocks, forests, swamps)	17,203	12.6
CYPR	Cypress swamp	5,545	4.0
MARS	Freshwater marsh/wet prairie/shrub swamp	16,945	12.5
WATR	Open water	9,020	6.6
GRAS	Grassland/improved pasture	24,455	17.9
CLCT	Clearcuts, shrub and brushland	14,986	11.0
DEVL	Developed (includes major roads)	10,934	8.0
Total		136,652	100.0

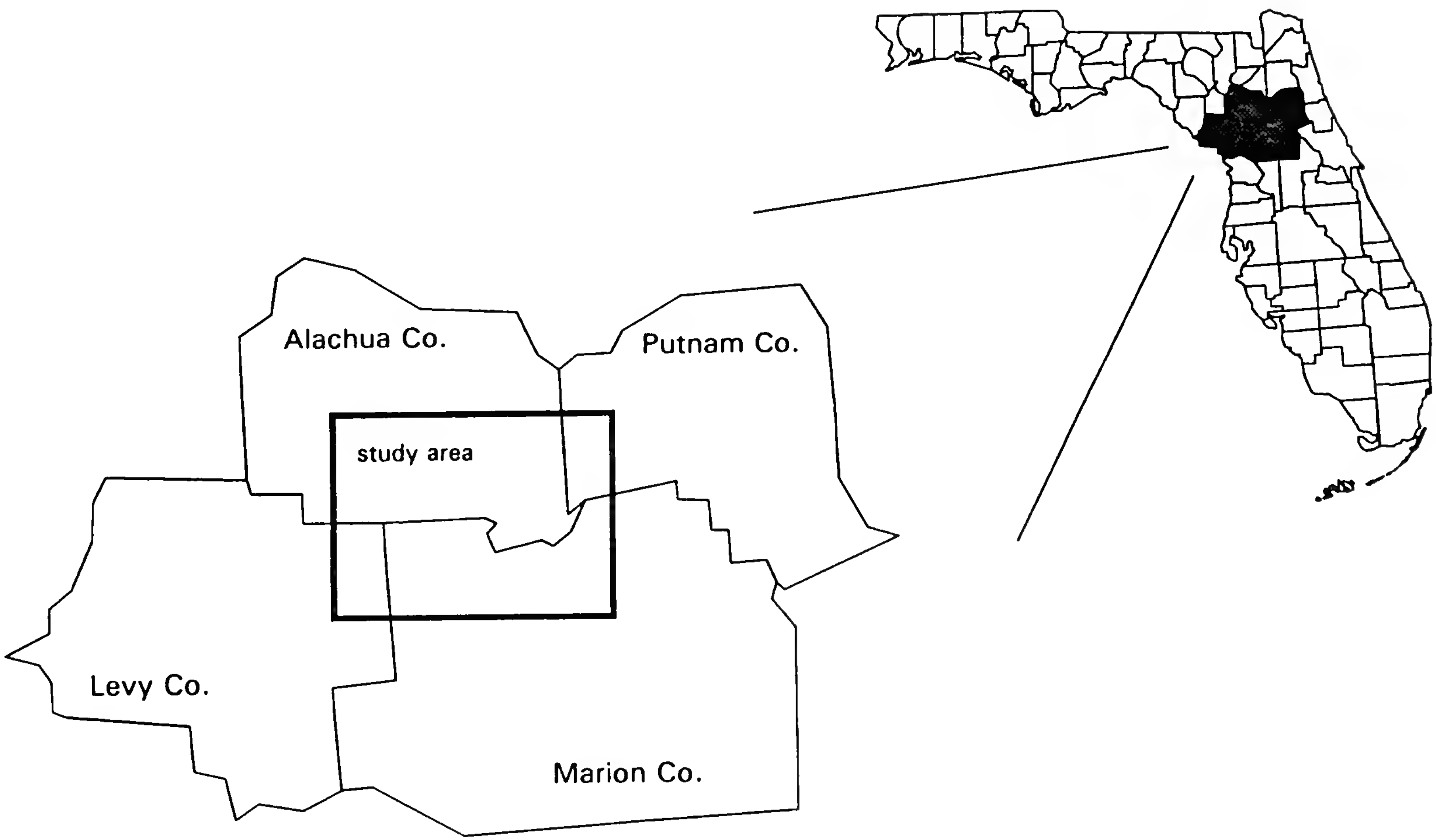

Figure 1-1. Study area in north-central Florida for bald eagle radio-tracking study, 1987 to 1991.

CHAPTER 2

POST-FLEDGING MOVEMENTS AND HABITAT USE

Introduction

Management emphasis and protection for bald eagles are focused at nest sites (U.S. Fish and Wildlife Service 1987) because it has been recognized that disturbance at nest sites can decrease productivity. Restrictions specified near nests remain in effect until young fledge. However, little is known about the post-fledging movements and habitat use of fledgling bald eagles prior to their first migration. Timing of initial migration and factors that influence it also are not well understood. These data are needed to determine if habitat management guidelines for eagle nests (U.S. Fish and Wildlife Service 1987) adequately address the habitat needs of fledglings. Because of the difficulty in locating and visually observing the increasingly active fledglings, I used radio-tracking as the most efficient method for obtaining movement and habitat use data for a large number of fledgling eagles.

Previous radio-tracking studies of fledgling eagles were conducted on the Chippewa National Forest, Minnesota (Harper 1974, Kussman 1976) and in Maine (McCollough 1986). A study using marked nestlings was conducted in Saskatchewan (Gerrard et al. 1974). All of these studies, however, dealt with birds in extremely different environments than are found in Florida.

I designed a study of fledgling eagles to address the following objectives using a twofold approach. I collected extensive data on radio-tagged nestlings and supplemented these data with intensive observations of nestlings at 2 nests. The objectives were:

1. Determine the length of time that fledgling eagles are dependent on their parents.
2. Characterize perch use, habitat use, and interactions with other eagles.
3. Determine the spatial needs of fledglings around the nest prior to migration.
4. Document the timing of initial migration by fledgling eagles and examine how this is influenced by sibling aggression, prey deliveries, temperature, precipitation, and/or water levels.

Methods

Banding and radio-tagging procedures

All known nests on the 2 study areas were surveyed once every 2 weeks between November and May, 1987-1991, with a Cessna 172 or 152. Surveys were used to document productivity of all breeding pairs and to determine dates for banding young and attaching radio transmitters.

A total of 122 nestlings were banded at 7-9 weeks of age with USFWS aluminum rivet bands (size 9) on the right leg. Eagles were removed from the nest by an experienced tree climber and lowered to the ground in a duffel bag where all banding and measuring took place. In 1987, a band tag with an alpha-numeric code was attached to each band. These tags were very difficult to see on free-flying birds. Consequently from 1988 to 1991, I attached wrap-around patagial markers made of Herculite fabric (Young and Kochert 1987) on the right wing. Each tag is yellow with a green shape indicating the year (1988=circle, 1989=square, 1990=triangle, 1991=circle) and a white two-digit number indicating the individual (Figure 2-1). They are highly visible from an airplane and allow much easier identification of young once they have fledged.

Additionally, 44 of the nestlings on the AMC study area were fitted with radio transmitters at 8-9 weeks of age. Transmitters (manufactured by Telemetry Systems, Inc.,

Mequon, Wisconsin) were back-pack mounted with 1-cm wide tubular teflon ribbon (Balley Ribbon Mills, Balley, Pennsylvania). All 4 harness ends were sewn together at one point on the breast with nylon thread to prevent loss of the package. Transmitters have a combination of solar panels that theoretically should last indefinitely, and rechargeable nickel-cadmium batteries with an estimated life of 4 years. Each transmitter package weighed approximately 55 g, about 1% of the weight of an average fledgling. They also were equipped with a mercury activity switch that facilitated locating individuals. A change in the signal pulse indicated when birds were moving rather than stationary.

I recorded a variety of physical measurements and estimated the fullness of the crop for each bird handled. Bortolotti (1984) determined that bill depth and length of foot pad were the two best indicators of sex for bald eagle nestlings, and length of the eighth primary was the best measure for estimating age. I initially judged the sex of each nestling in the field using these measurements and the relative size and appearance of each bird. I then used discriminant function analysis of bill depth and length of the foot pad to confirm the sex of each bird (Figure 2-2). At nests with 2 chicks, I estimated hatch order using length of the eighth primary.

<u>Intensive nest observations</u>

Post-fledging behavior and habitat use were recorded for fledglings at 2 nests (AL32A and MR17D) on the study area in 1991. Nest AL32A was in a pine tree located in a 57 ha pasture with a few scattered pines. Nest MR17D was in a pine tree in a small patch of woods (0.7 ha) surrounded by small patches of pasture, marsh, and woods. Observations began when nestlings were approximately 9 weeks old and continued until the young left the nest area. At nest AL32A, young appeared to have initiated migration when they left the nest area. At nest MR17D, the patchy landscape made it difficult to follow the movements of fledglings; observations were discontinued prior to migration.

Two young at each nest site were observed 2 consecutive half days each week to document spatial use of the nest area and behavioral interactions between parents and young prior to dispersal. This resulted in 1 full day of observations from just before dawn to just after dusk per week. Data recorded every 15 minutes included location (measured from topographic maps with a 45.7 m grid) and activity of each fledgling and number of adults present. In addition, all interactions (between fledglings, between fledglings and adults, or between fledglings and other species) and all prey items delivered were recorded.

I calculated the distance each fledgling was located from the nest during each 15 minute observation. Analysis of variance and Waller-Duncan K-ratio t-tests were used to examine distance from the nest in relation to age for fledglings at each nest. Intensive data collected from birds at these 2 nests were used to supplement the extensive data collected from radio-tagged nestlings.

Extensive radio-tracking surveys

From 1987 to 1990, 41 nestlings fitted with transmitters were monitored from 8-weeks-of-age until they left the study area (3 died prior to fledging--Chapter 5). Fledglings were considered to have initiated migration when they could not be located within the study area by aerial radio-tracking. Each bird was located from 1 to 22 ($\overline{x} = 8$) times using aerial and ground surveys for a total of 372 locations. For each location, data were recorded on date, time, location, activity, habitat, and association with other eagles.

Age at migration was calculated as the mid-point between the last date an individual was located on the study area and the date of the next survey when the individual was not located. I used analysis of variance to test for a year effect on migration age. I used t-tests to examine mean distance to the natal nest and age of migration in relation to sex, number of chicks in the nest, timing of fledging and hatch order. I used linear regression to examine the

relationship between age at migration and hatching date. Data were weighted to account for repeated observations on individuals where appropriate.

Climate and water level data

I obtained water level data for Alachua Lake from Paynes Prairie State Preserve, Florida Department of Natural Resources. Water level data for Lochloosa, Newnans and Orange lakes were obtained from the U.S. Geological Survey (U.S. Geological Survey 1987-1991). I plotted mean monthly water levels in feet NGVD (National Geodetic Vertical Datum of 1929) for each of these lakes (Figure 2-3). Maximum and minimum daily temperatures and daily precipitation recorded at Gainesville Regional Airport (National Oceanic and Atmospheric Administration 1987-1991) were summarized into monthly mean temperatures (Figure 2-4) and total monthly precipitation (Figure 2-5).

Results

Over the 5 years that I banded eagles, 58 of the banded nestlings were male and 54 were female (Figure 2-2). Discriminant function analysis of bill depth and foot pad measurements found that only one individual was originally misclassified. Consequently, this bird identified as a male in the field was reclassified as a female because its measurements (bill depth = 30.4 mm, foot pad = 129 mm) were more within the range found for all females (Table 2-1). For radio-tagged individuals, 26 were classed as male and 18 were female (Table 2-2).

Extensive radio-tracking surveys

Prior to fledging, all observations of radio-tagged young during aerial surveys were birds perched in the nest or in the nest tree. Nestlings were considered to have fledged at 11 weeks of age. After fledging, 91% of all sightings (n=289) were of perched birds, 8% were flying, and 1% were soaring. Of the 202 observations of perched fledglings, 45% were in

the nest. Fledglings perched in pine trees accounted for 39% of all observations. This reflects the preponderance of eagle nests in pine trees. All other observations of perched birds occurred in snags (6%), cypress (1%), hardwoods (1%), other trees (1%), and on the ground (1%).

I recorded 60 instances during aerial surveys where radio-tagged fledglings were perched with other eagles. Eagles were perched with siblings on 75% of the observations, 22% with adults, and 3% with both adults and siblings. The adults present during these observations most likely were the parents as they were perched at or very near the natal nest site.

Two birds were located >10 km (11.5 and 32.2 km) from the nest on the last date each was located on the study area. Since neither was located on the next aerial survey, I assumed the previous location represented the initiation of migration. These 2 locations and locations of birds prior to fledging were excluded from calculations of the mean distance fledglings ranged from the nest.

Radio-tagged fledglings generally were located close to the nest. The mean distance for 40 individuals was 0.2 km (Table 2-3). The maximum distance a fledgling was located from its nest was 4 km. There was no difference in relation to sex or timing of fledging; however, fledglings with a sibling tended to range significantly farther from the nest than those from nests with only 1 young (Table 2-3).

Over the 4 years, the earliest date a fledgling was last seen on the study area was 23 April 1989; the latest date was 30 July 1987. The earliest and latest dates varied each year (Table 2-4). The average date immatures left the study area was 8 June. Fledglings tended to migrate when water levels were dropping (Figure 2-3), when temperatures were approaching or at their annual high (Figure 2-4), and when fish abundance was at an annual high and beginning to decline (Figure 2-6). Precipitation (Figure 2-5) did not appear to be

correlated with migration. The mean and maximum dates for migration in 1989 and 1990 were 1 month earlier than in 1987 and 1988, possibly related to a prolonged drought. The drought caused water levels to drop on all lakes and wetlands in 1989; in 1990, many wetlands became completely dry.

The estimated age fledglings migrated from the study area ranged from 104 to 153 days of age (Table 2-2), with an average of 127 days (7 weeks post-fledging) (Table 2-5). Data for the 4 years were combined because there was no year effect on migration age ($F = 0.64$, $\underline{P} = 0.60$). There also was no difference in the age at which young migrated from the study area in relation to sex, timing of fledging, number of chicks that fledged from a nest, or order of hatching (Table 2-5). Similarly, linear regression analysis of migration age and hatch date showed no relationship ($R^2 = 0.009$) (Figure 2-7). The largest difference in migration age occurred for order of hatch. First-hatched birds tended to migrate at a younger age than second-hatched birds.

<u>Intensive nest observations</u>

As I observed with radio-tagged young, nestlings under intensive observation were perched during the majority of the 727 observations (97.4%). Fledglings were most often perched in the nest tree, either in limbs adjacent to the nest (39.4%) or in the nest itself (19.8%) (Figure 2-8). I recorded 5 activities for bald eagles during the nest observations: exercise, fly, feed, perch, and soar (Figure 2-9). Fledglings spent most of their time perched (85.1%). They spent very little time flying or soaring. The second most common activity was feeding, accounting for 10.2% of the observations.

I recorded 50 associations/interactions between fledglings, fledglings and adults, and fledglings and other birds (Table 2-6). A fledgling perched with its sibling accounted for 40% of the interactions. It was uncommon for fledglings to perch with their parents (12% of observations), as adults rarely were present at or near the nest. Twelve aggressive

interactions (aggressive posturing and biting) between siblings were observed. All 8 cases of aggressive posturing occurred at nest AL32A; 5 of these were associated with the possession of prey. The older and larger female in all 5 food-related cases dominated the younger male sibling. The 3 instances of aggressive posturing of the younger male towards the female occurred when the female returned to the nest from a bout of flying. The 2 biting interactions at this nest also were initiated by the female during food conflicts. All aggressive interactions occurred on or before 30 April, at least 1 week before the older sibling migrated. At nest MR17D, 2 biting interactions were observed, one initiated by each sibling. No aggressive interactions between chicks and adults were observed at either nest.

A fledgling eagle was observed interacting with other bird species only 3 times (Table 2-6). A red-tailed hawk (Buteo jamaicensis) and 2 loggerhead shrikes (Lanius ludovicianus) stooped on this fledgling. Turkey vultures (Cathartes aura) were chased by this same fledgling.

I observed 15 prey deliveries at the 2 nests under observation (Table 2-7). In addition, at least 9 other prey items had already been delivered to the nest when observation sessions began. When young were observed feeding on fresh prey before any deliveries were recorded for the day, the prey item being consumed was considered a delivery for the day, although it might have occurred late the day before.

At nest AL32A, 0 to 3 prey items were delivered during each half-day observation (Table 2-7). The older sibling from this nest left the nest area between 7 and 13 May when prey still was being delivered by the adults. The younger sibling left the area on 13 or 14 May. On its last day of observation, no prey deliveries were observed and it frequently vocalized and followed the adult male. Prey deliveries were difficult to observe at nest MR17D due to thick vegetation and became impossible once fledglings began spending considerable time away from the nest tree.

Young at both nests were first observed away from the nest tree at approximately 13 weeks of age, and continued using the nest tree up to 16 (MR17D) and 17 (AL32A) weeks of age. The distance that fledglings were observed from the nest varied significantly with age for both nests (AL32A: $F = 38.26$, $P = 0.0001$; MR17D: $F = 40.32$, $P = 0.0001$; Table 2-8). As young became older and more skillful at flying, they moved farther from the nest (Table 2-8). At nest AL32A, fledglings remained significantly closer to the nest prior to 18 days post-fledging than they did at older ages.

The maximum distance any fledgling was observed perched from either of the 2 nests was 0.9 km (with 1 exception, see below). They undoubtedly ranged farther than this, however, because those at nest AL32A were lost from view on a few occasions while soaring and those at nest MR17D were lost from view in the dense trees. An immature eagle believed to be one of the fledglings from nest AL32A was seen perched approximately 8.3 km from the nest, near the area its parents used for foraging. At this time (5/14/91), the fledgling would have been approximately 17 weeks of age. This was the last time this eagle was observed. Attempts to locate it in the vicinity of the nest on the following day were unsuccessful. The distant perch site appeared to be a precursor movement to migration.

Discussion

Nestlings at 8 weeks of age in this study had slightly smaller bill depth and foot pad measurements (Table 2-1) than eagles of a similar age hatched from eggs collected in Florida and raised in captivity. The mean bill depth for captive-raised birds was 31.3 mm for females (n=20) and 29.0 mm for males (n=28) (A. Jenkins, pers. commun.). Likewise, mean foot pad length was 134.6 mm for females and 123.2 mm for males. Fledglings raised in captivity were supplied with unlimited amounts of food and probably attained maximum size for southern bald eagles, unlike wild nestlings that might have experienced periods of food

shortage. In contrast, the northern subspecies (H. l. alascanus) is larger than either wild or captive-raised H. l. leucocephalus nestlings. Bill depth in H. l. alascanus is approximately 33.3 mm for females and 30.1 mm for males, while foot pad length is 147.1 mm for females and 131.8 mm for males (Bortolotti 1984).

In Maine, young fledged over a 34 day span (11 July to 14 August; McCollough 1986); in Florida, fledging occurs over a longer time span. Radio-tagged birds in this study fledged from about 25 March to 27 May, a 63 day span. Because I did not make daily observations, these fledging dates are not precise.

The distance fledglings perched from the nest tree in Maine ranged from 0.4 to 2.7 km (McCollough 1986), while the maximum distance young were observed to perch from the nest in Minnesota was 6.9 km (Kussman 1976). Gerrard et al. (1974) reported that most fledglings stayed within 1.6 km of the nest for approximately 7 weeks after fledging. In this study, the maximum distance a radio-tagged fledgling was located from its nest was 4 km. Intensive observations at 2 nests showed that fledglings remained within 400 m of the nest for approximately 5 weeks post-fledging. Generally, it appears that fledglings remain in close proximity to the nest site until they initiate migration.

McCollough (1986) observed a decrease in food deliveries 6 to 8 weeks after young fledged. He concluded that reduced feeding likely initiated migration. Herrick (1934) also observed a reduction in food deliveries at one nest. However, at the same nest the following year and at a second nest, he saw no decrease in food deliveries. Kussman (1976) observed no decrease in the number of prey items brought to a nest in Minnesota. It is unknown if the biomass of food delivered in these studies changed over time during post-fledging. At one nest, I observed no decrease in the number of food deliveries before the older sibling migrated; however, food deliveries decreased before the younger sibling migrated. Perhaps if young do not leave on their own, food deliveries are decreased by adults, possibly in response

to declining prey availability. Fish availability declined on at least one lake on the study area during the later months fledglings leave on migration (Figure 2-6).

As I observed in this study, Harper (1974), Kussman (1976), and McCollough (1986) all indicated that fledgling eagles relied almost exclusively on their parents for food and observed no active hunting before initiation of migration. Only Kussman (1976) observed 3 instances of scavenging of fish on sand beaches of nearby lakes. The earliest age at which scavenging was observed was 46 and 60 days post-fledging.

The age at which fledglings left their natal sites varied in other studies as well, ranging from 112 to 147 days of age (Harper 1974, Kussman 1976, McCollough 1986) with only 1 individual leaving after 196 days of age (Harper 1974). The range of ages young left the Florida study area was similar (104-153). Apparently, a certain amount of time is required for fledglings to initiate migration regardless of their geographic origin, perhaps to reach a physical condition capable of sustaining them during long-distance migration. The older chick generally migrated first. It frequently dominated prey delivered to the nest and likely builds up adequate reserves for migration more quickly.

I expected late-fledging young to migrate from the study area at a younger age; however, a linear regression analysis showed no such relationship. This suggests that the timing of migration is tied more to prey abundance than to seasonal changes in temperature. If migration was tied to temperature one would expect late-fledging young to leave more quickly (at a younger age) before temperatures became high. Perhaps at nests with greater food availability, fledglings might migrate at a younger age because they can reach peak condition more quickly. However, additional prey availability data are needed to test this hypothesis.

The bald eagle habitat management guidelines (U.S. Fish and Wildlife Service 1987) specify a primary protection zone with a boundary range of 229-457 m (750-1500 feet) from

any bald eagle nest used for breeding in the southeastern United States. Residential, commercial, or industrial development, tree cutting, logging, and use of chemicals toxic to wildlife are prohibited in this zone. Unauthorized human entry is restricted during the breeding season. In Florida, the primary zone boundary is set at 229 m; development occasionally is permitted within this zone. Restrictions are enforced until nestlings fledge.

The protection zones specified around nests in the habitat management guidelines are not as large as the maximum distance of 4 km that radio-tagged fledglings were seen from the nest. The mean distance of 0.16 km was well within the boundary of the smaller primary zone (229 m), reflecting use of the nest by fledglings as the hub of their activities. Fledglings observed intensively at 2 nests stayed within the 229 m boundary only until approximately 3 weeks post-fledging (Table 2-8). By approximately 6 weeks post-fledging these eagles had ranged outside of the boundary of the larger (457 m) primary zone. To protect the amount of habitat that is sufficient for the needs of fledglings and to prevent disturbance that may cause premature migration, the boundary of the primary zone should be at least 457 m from the nest.

Restrictions in human activity around nest sites also must allow for the time fledglings remain dependent on the adults and the nest site, approximately 7 (range 4-11) weeks post-fledging. Currently, protection from disturbance as inferred from the bald eagle habitat management guidelines (U.S. Fish and Wildlife Service 1987) extends only until the time young fledge. Disturbance near a nest while fledglings still are dependent on adults may prevent adults from supplying adequate amounts of food to dependent young or cause premature dispersal of young before they can build up adequate food reserves.

Migration is energetically demanding, particularly to young and inexperienced birds. Fledglings in less than optimum physical condition when initiating migration may be less

likely to survive the energetic demands of migration. It appears that fledglings may not stop to forage during their initial stages of migration (A. Jenkins, pers. commun.). At least 5 birds from this study traveled more than 100 km per day indicating rapid movement north (see Chapter 3). This rapid movement north, in concert with little foraging, emphasizes the need for fledglings to be in optimum physical condition to withstand the rigors of migration.

Table 2-1. Bill depth (mm) and length of foot pad (mm) for 8-week-old bald eagle nestlings in north-central Florida from 1987 to 1991.

Variable	Sex	n	$\bar{x}$	SE	Range
Bill depth	F	54	31.1	0.11	29.4-33.3
	M	58	28.3	0.12	26.4-30.6
Foot pad	F	46	133.3	0.71	122-141
	M	58	121.1	0.63	104-129

Table 2-2. Hatching dates, migration dates, and perch distance for bald eagle nestlings fitted with solar-powered radio transmitters, 1987 to 1990, in north-central Florida.

Nest number	Radio frequency	Sex	Estimated hatch date	Last date in study area	Estimated age at migration (days)	Maximum distance from nest (m)
1987						
AL-7A	165.100	M	3/9/87	7/30/87	145	524
LV-25	165.520	M	3/7/87	7/10/87	129	243
AL-7A	165.616	M	3/9/87	7/30/87	145	423
AL-27	165.675	F	2/5/87	7/2/87	151	802
AL-35	165.718	F	2/5/87	6/3/87	122	0
MR-108	165.861	F	2/5/87	6/10/87	126	639
AL-17C	165.881	F	2/9/87	6/16/87	132	368
AL-35	165.942	F	2/5/87	5/27/87	115	0
AL-33	165.958	F	3/14/87	7/2/87	113	0
AL-19	165.999	F	2/5/87	6/3/87	122	0
1988						
AL-15A	165.081	M	1/28/88	5/11/88	108	0
AL-10	165.145	F	2/22/88	6/23/88	124	0
MR-107	165.155	F	2/12/88	6/17/88	127	412
AL-17B	165.180[a]	F	2/22/88	-	-	-
AL-14	165.212[a]	F	2/22/88	-	-	-
AL-40	165.241	M	2/22/88	7/7/88	138	0
AL-40	165.262	M	2/22/88	7/7/88	138	0
AL-24A	165.418	M	3/8/88	6/28/88	112	0
AL-24A	165.561	F	3/8/88	7/13/88	129	294
AL-33	165.593	M	3/11/88	7/25/88	137	505
AL-32A	165.957	M	1/11/88	5/6/88	119	0
AL-32A	165.998	F	1/11/88	5/6/88	119	0
1989						
AL-33	164.197	M	2/1/89	6/23/89	143	582
AL-28C	164.399	F	1/14/89	5/11/89	121	3968
AL-10	164.496	M	2/1/89	5/26/89	117	0
AL-40	164.738	M	2/8/89	5/19/89	104	0
AL-26A	164.756	M	2/5/89	5/3/89 ?	(radio out?)	0
AL-28C	164.798	M	1/14/89	5/18/89	124	681
AL-40	164.814	M	2/8/89	6/21/89	137	2996
AL-1A	164.895	M	2/28/89	6/28/89	123	0
AL-24A	164.897[a]	M	???	-	-	-
AL-3B	165.210	M	1/19/89	5/26/89	130	566
AL-17A	165.698	M	1/2/89	4/23/89	117	1076
AL-17A	165.755	M	1/2/89	6/1/89	153	1137
AL-3B	165.933	M	1/19/89	5/26/89	130	566

Table 2-2 cont.

Nest number	Radio frequency	Sex	Estimated hatch date	Last date in study area	Estimated age at migration (days)	Maximum distance from nest (m)
<u>1990</u>						
AL-50	164.011	M	1/16/90	5/20/90	126	0
AL-32A	164.033	M	1/16/90	5/15/90	121	0
AL-26A	164.666	F	2/8/90	6/10/90	124	349
AL-32A	164.902	M	1/16/90	5/15/90	121	0
AL-43	164.963	F	1/22/90	5/26/90	126	0
AL-29A	164.969	F	3/5/90	6/21/90	112	240
AL-3B	165.570	M	1/16/90	5/26/90	132	137
AL-3B	165.580	M	1/16/90	5/26/90	132	137
AL-1A	165.992	F	2/8/90	6/21/90	137	450

[a]Recovered dead prior to fledging.

Table 2-3. Distance (km) fledgling bald eagles were located from their natal nest prior to initiation of migration by sex, number of chicks fledged from nest, and timing of fledging, 1987 to 1990 in north-central Florida.

Variable	n	wn[a]	$\bar{x}$	SE	t	P
Sex						
F	110	15	0.12	0.06		
M	182	25	0.18	0.06	-0.66	0.52
Number of chicks						
1	104	14	0.05	0.02		
2	186	26	0.22	0.07	-2.35	0.03
Timing of fledging[b]						
Late	169	18	0.12	0.05		
Peak	121	22	0.19	0.08	-0.74	0.46
Total	292	40	0.16	0.05		

[a]wn = sample size when weighted for repeated observations on individuals
[b]Late = last 25% and peak = first 75% of all clutches laid within a breeding season.

Table 2-4. Earliest and latest dates fledgling bald eagles were last located on the study area in north-central Florida, 1987 to 1990.

Year	n	$\bar{x}$	Minimum	Maximum
1987	10	24 June	27 May	30 July
1988	10	18 June	6 May	25 July
1989	12	26 May	23 April	28 June
1990	9	31 May	15 May	21 June
Total	41	8 June	23 April	30 July

Table 2-5. Age (number of days after hatch) at which fledgling bald eagles left the north-central Florida study area in relation to sex, timing of fledging, number of chicks fledged from a nest, and order of hatch, 1987 to 1990.

	n	$\bar{x}$	SE	Minimum	Maximum	t	P
Sex							
Female	17	125	2.3	112	151	-1.09	0.28
Male	23	129	2.6	104	153		
Timing of fledging[a]							
Late	18	128	2.8	104	145	0.54	0.59
Peak	22	126	2.4	108	153		
Number of chicks							
1	13	127	3.6	108	151	-0.10	0.92
2	27	127	2.1	104	153		
Order of hatch							
1	15	124	2.6	104	145	-1.56	0.13
2	13	131	2.9	115	153		
Total	40	127	1.8	104	153		

[a]Late = last 25% and peak = first 75% of all clutches laid within a breeding season.

Table 2-6. Interactions observed for fledgling bald eagles at 2 nests in north-central Florida after 11 weeks of age, 1991.

Interaction	C - C[a]	C - A	O - C
Stooped on			2
Chased by			1
Perch together	20	6	
Flying together	4	2	
Fed by		3	
Aggressive posturing	8		
Bites at	4		

[a]C = chick, A = adult, O = other (red-tailed hawk, loggerhead shrike, turkey vulture). First letter is individual that initiated interaction; second letter is individual that received it.

Table 2-7. Prey deliveries post-fledging at 2 bald eagle nests in north-central Florida in 1991. Nestlings were considered fledged at 11 weeks of age (AL32A = 4 April 1991, MR17D = 22 April 1991).

Nest number	Date	Days post-fledging	Number prey deliveries Observed	Assumed[a]
AL32A	4/11/91	7	0	0
	4/12/91	8	0	1
	4/16/91	12	0	1
	4/17/91	13	2	0
	4/22/91	18	1	1
	4/23/91	19	2	0
	4/29/91	25	1	0
	4/30/91	26	2	0
	5/6/91	32	1	1
	5/7/91	33	2	1
	5/13/91	39	0	1
	5/14/91	40	0	0
MR17D	4/27/91	5	0	0
	5/1/91	9	1	1
	5/8/91	16	1	1
	5/9/91	17	1	1
	5/15/91	23	1	0

[a]Assumed prey delivery because young observed feeding on fresh prey when nest observations began.

Table 2-8. Distance (m) from the natal nest in north-central Florida that fledgling bald eagles were located in relation to days post-fledging in 1991. Nestlings were considered fledged at 11 weeks of age. For each nest, means with the same letter are not significantly different (Waller-Duncan K-ratio t-test).

Nest number	Days post-fledging	n	$\bar{x}$		SE	Range
AL32A	7	50	0	D	0.0	0 - 0
	8	50	0	D	0.0	0 - 0
	12	55	0	D	0.0	0 - 0
	13	38	10	D	6.7	0 - 183
	18	53	17	D	4.0	0 - 102
	19	52	88	C	9.4	0 - 188
	25	58	154	B	12.4	0 - 233
	26	52	93	C	11.7	0 - 233
	32	42	150	B	14.2	0 - 233
	33	45	220	A	24.6	0 - 421
	39	28	67	C	7.2	0 - 91
	40	21	149	B	45.3	0 - 867
MR17D	5	28	0	D	0.0	0 - 0
	9	58	0	D	0.0	0 - 0
	16	29	0	D	0.0	0 - 0
	17	42	16	C	4.3	0 - 102
	23	45	52	B	7.1	0 - 129
	30	10	0	D	0.0	0 - 0
	36	11	101	A	3.3	91 - 129
	37	6	57	B	16.0	0 - 102

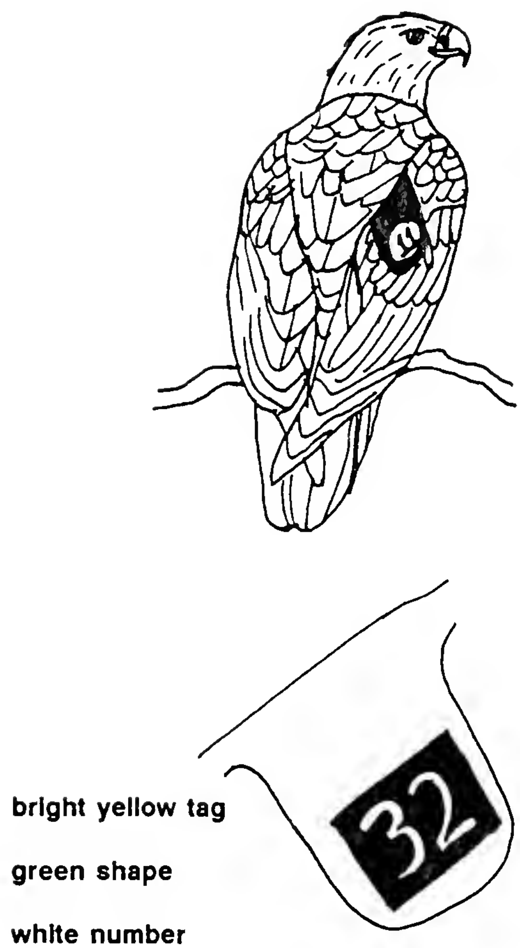

Figure 2-1. Patagial marker attached to nestling bald eagles in north-central Florida and its location on the right wing of the bird.

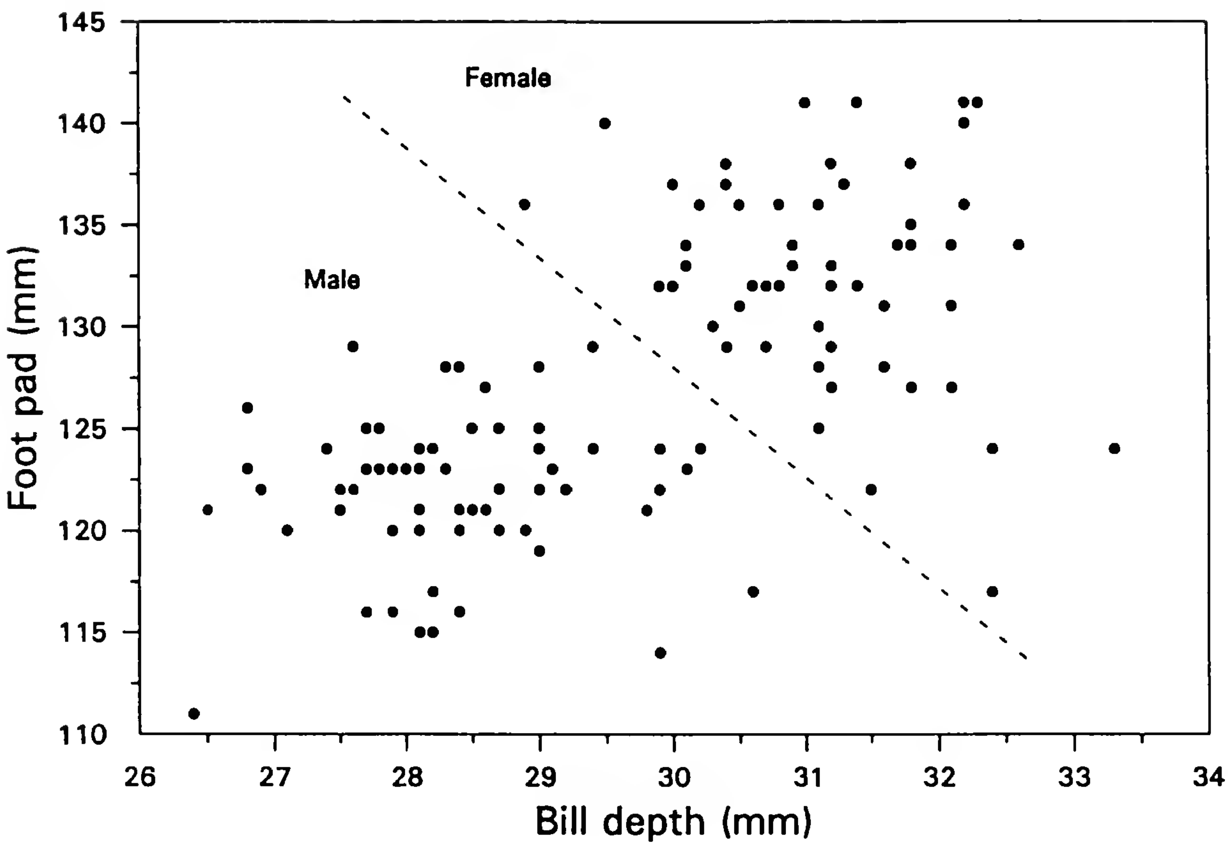

Figure 2-2. Measurements of bill depth (mm) and foot pad (mm) for 8-week old nestling bald eagles in north-central Florida.

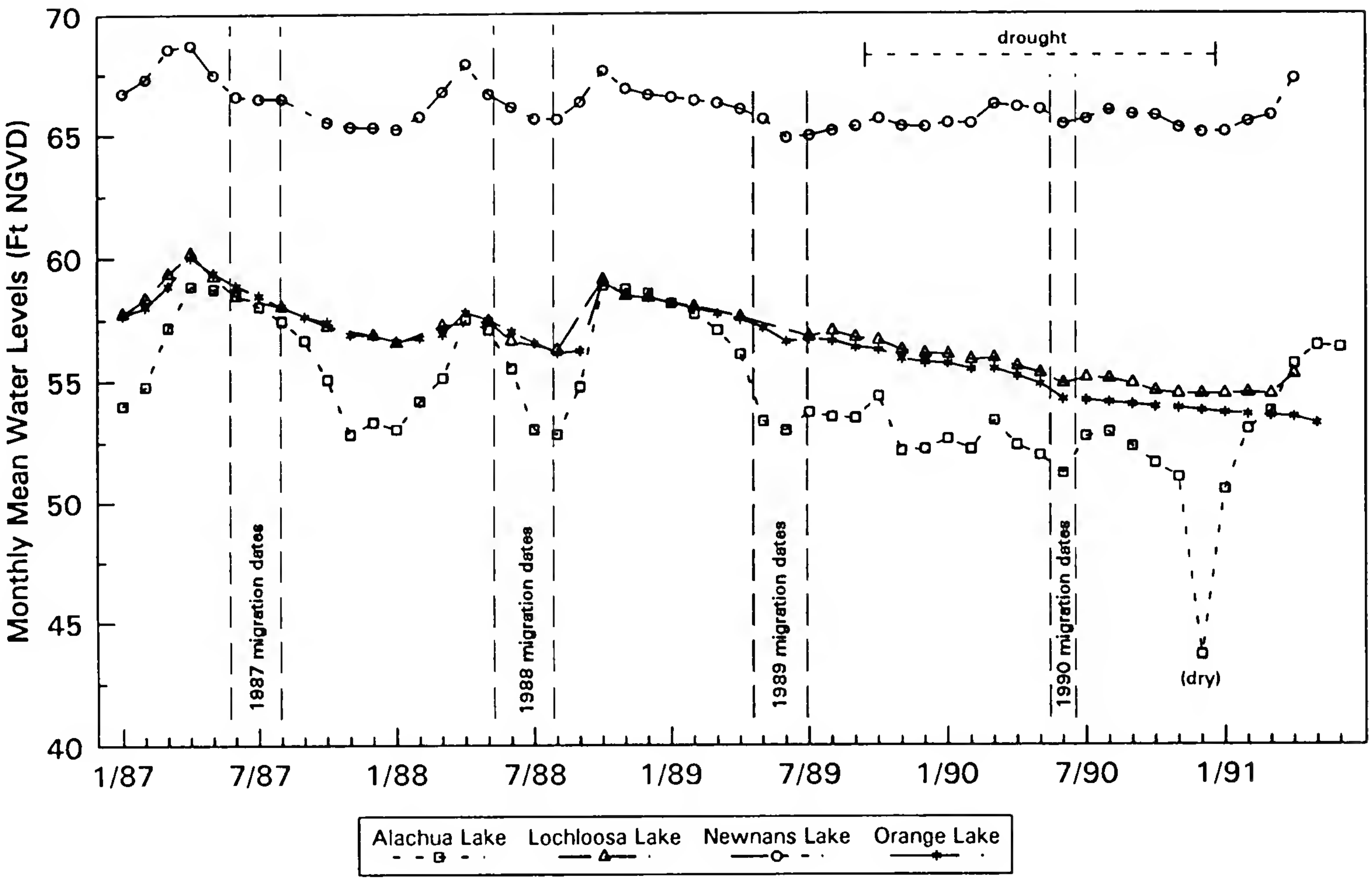

Figure 2-3. Mean monthly water levels (in feet NGVD) from January 1987 to June 1991 for Alachua, Lochloosa, Newnans and Orange Lakes, Florida. Migration dates are for radio-tagged fledgling bald eagles on their initial migration from the study area.

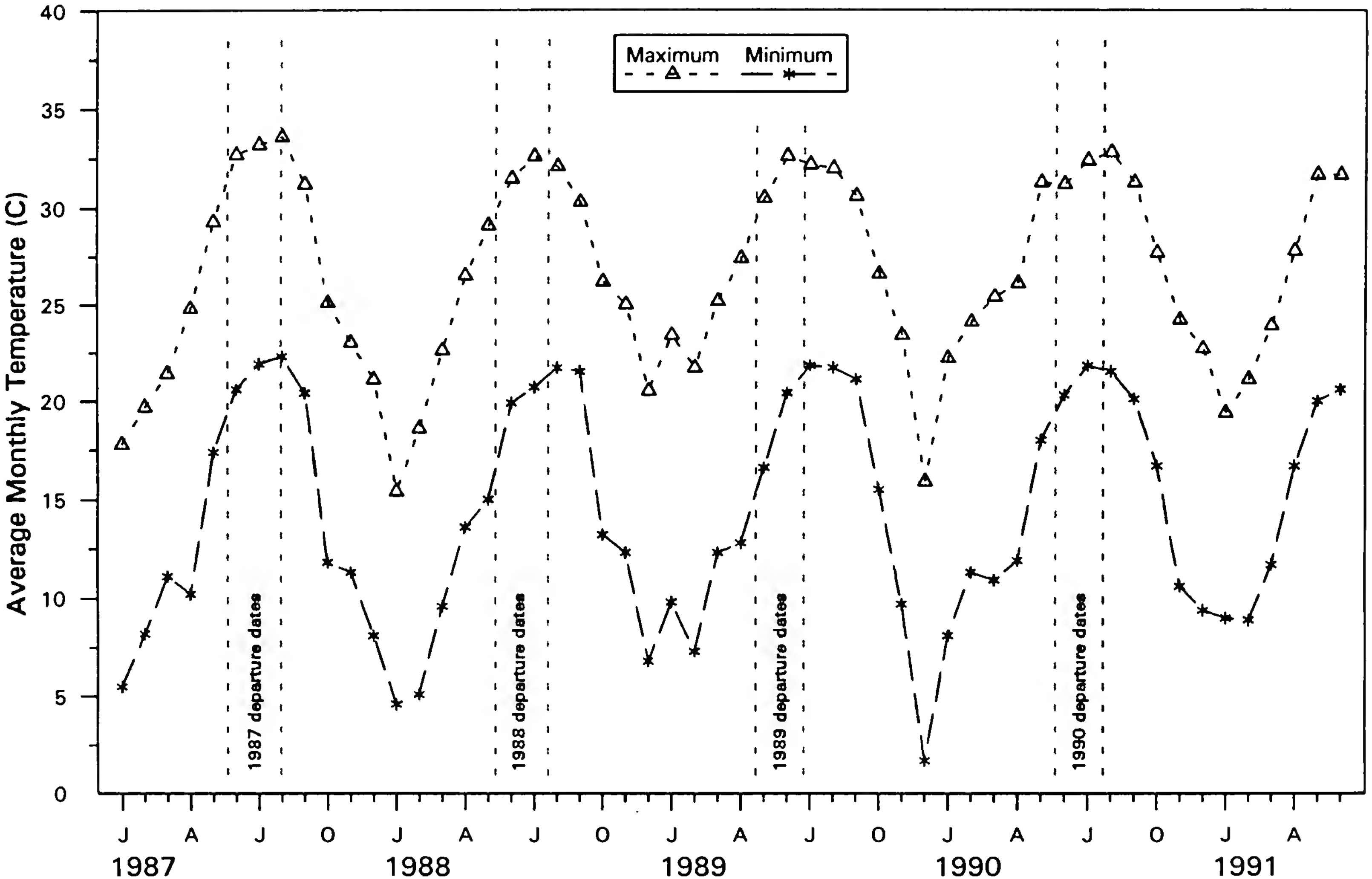

Figure 2-4. Average monthly maximum and minimum temperatures (°C) measured at Gainesville Regional Airport from January 1987 to January 1991. Migration dates are for radio-tagged fledgling bald eagles on their initial migration from the study area.

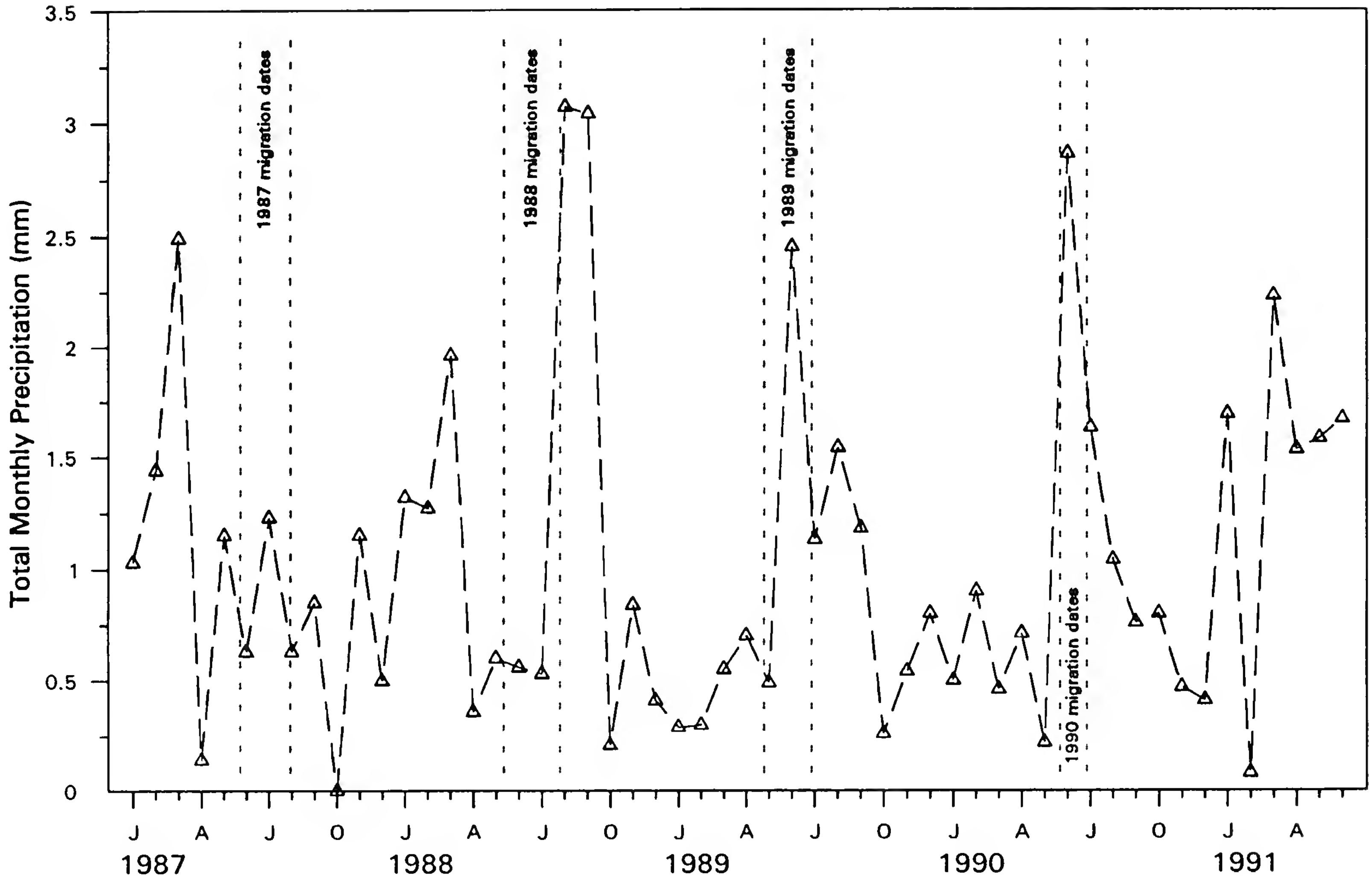

Figure 2-5. Total monthly precipitation (mm) measured at Gainesville Regional Airport from January 1987 to January 1991. Migration dates are for radio-tagged fledgling bald eagles on their initial migration from the study area.

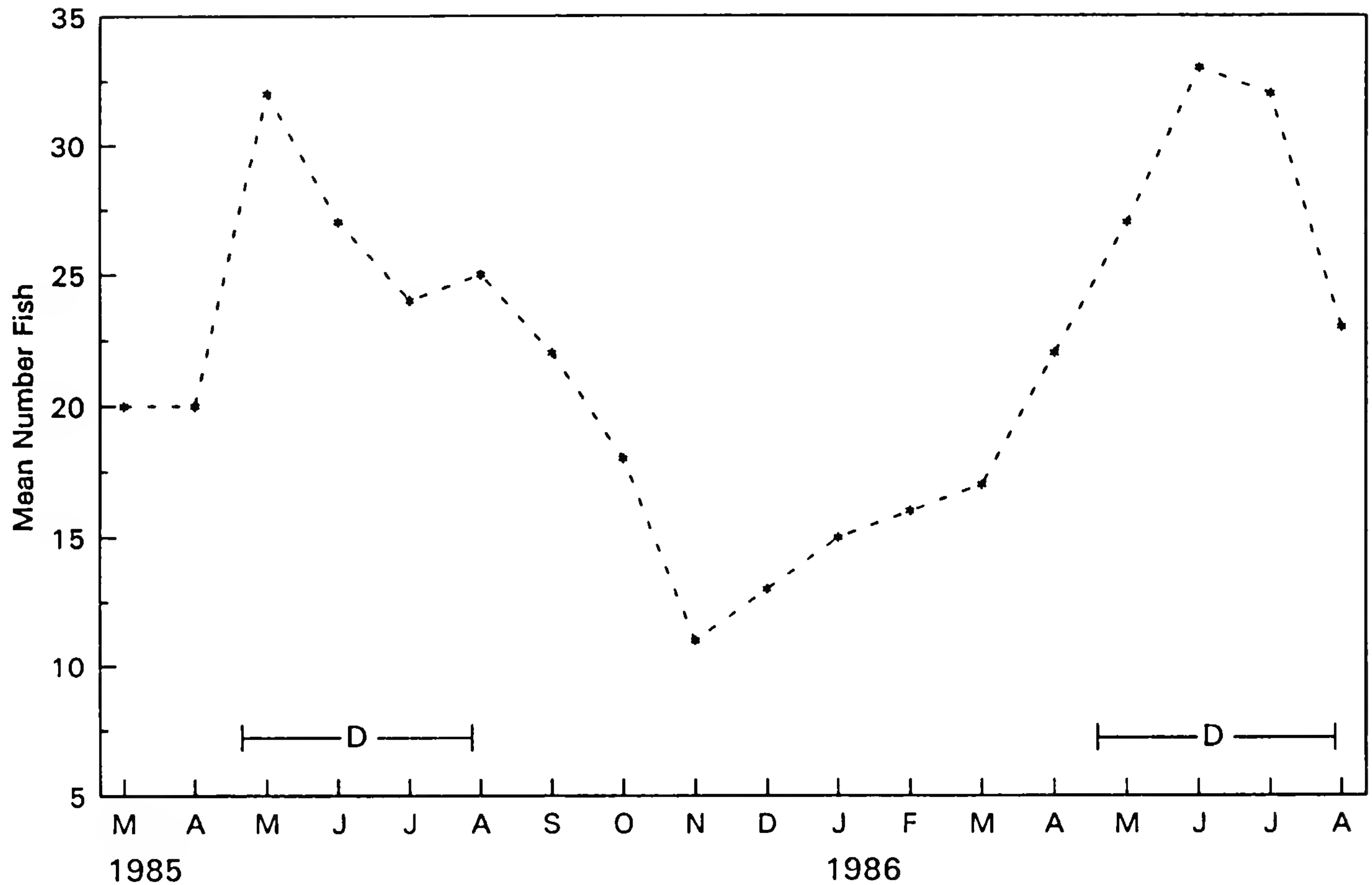

Figure 2-6. Mean number of fish electro-shocked on monthly transects on Newnans Lake (data from Edwards 1987) in relation to mean departure (D) dates for radio-tagged fledgling bald eagles on their initial migration away from the study area.

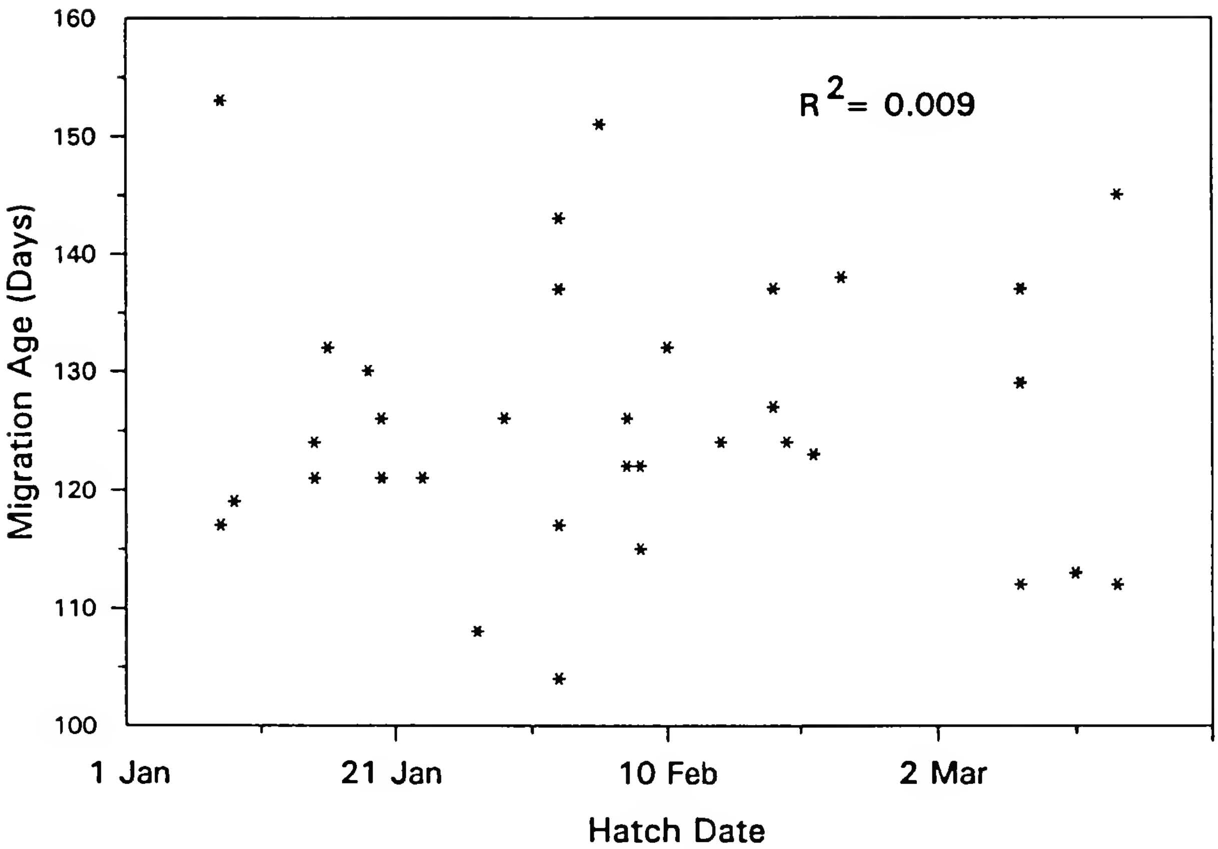

Figure 2-7. Relationship between age radio-tagged fledgling bald eagles began their initial migration from the study area and timing of hatching.

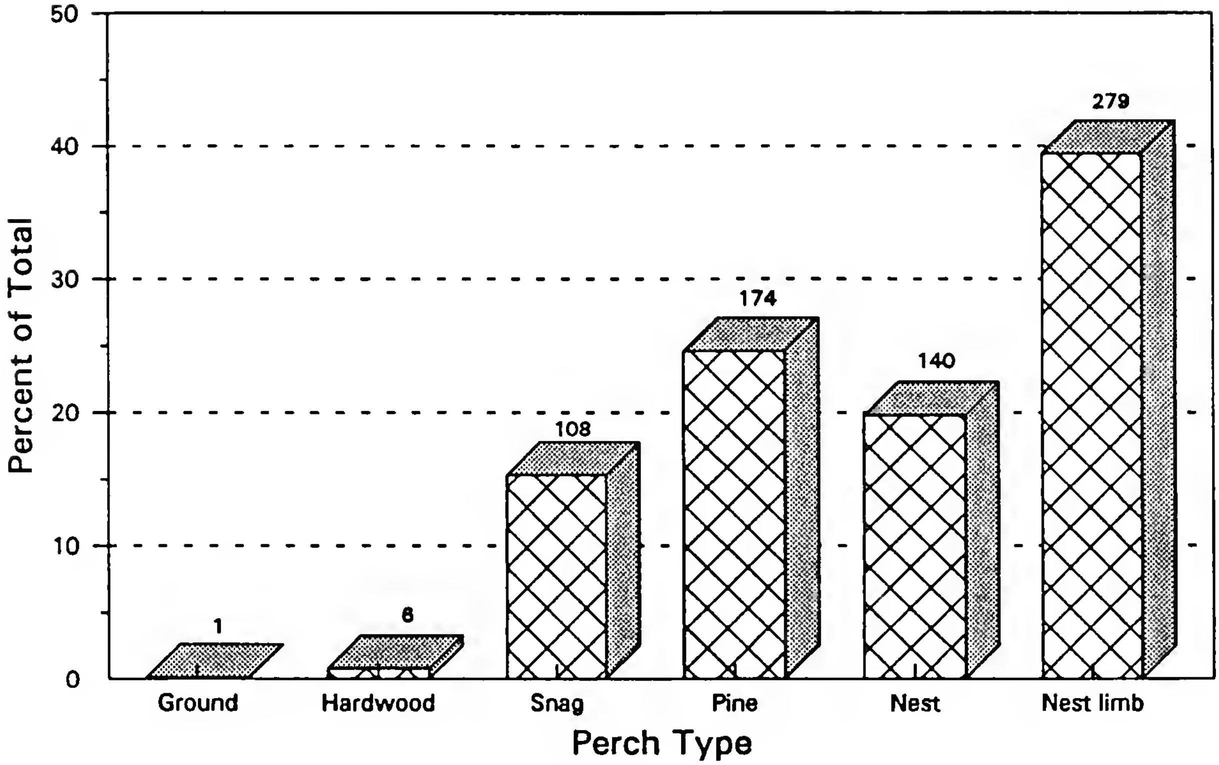

Figure 2-8. Perch use of fledgling bald eagles under intensive observation in 1991 at 2 nests in north-central Florida.

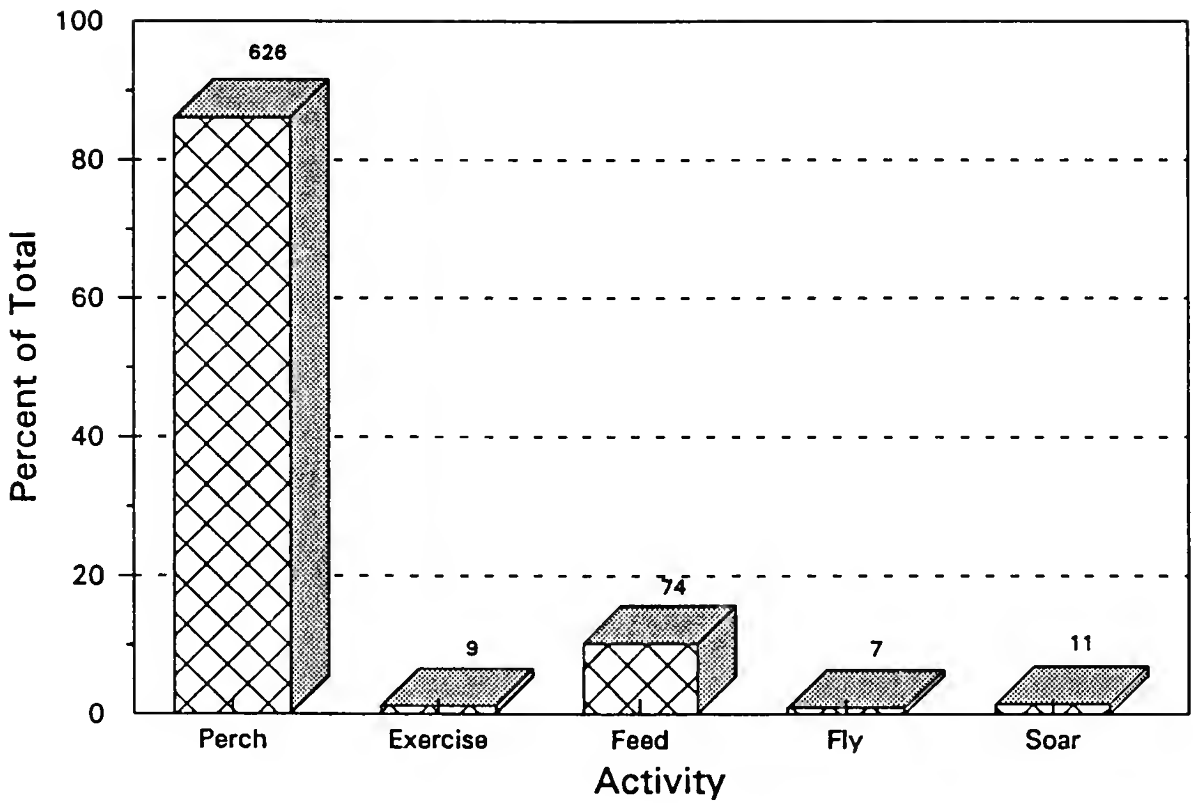

Figure 2-9. Activity of fledgling bald eagles under intensive observation in 1991 at 2 nests in north-central Florida.

CHAPTER 3

MIGRATORY PATTERNS OF SUBADULT BALD EAGLES

Introduction

Avian migration patterns have been studied extensively (Gauthreaux 1982). Partial migration, characterized by some individuals of a population remaining at or near the breeding grounds, occurs in a large number of species (Lack 1954). In populations with this migration strategy, predominantly young birds migrate and females migrate more than males (Gauthreaux 1982). Bald eagles in different portions of their range exhibit various migration patterns. Maine populations are partial migrants (McCollough 1986), Chesapeake Bay populations do not migrate (Buehler et al. 1991b), while in some Canadian populations all individuals appear to migrate (Gerrard et al. 1978). The migration strategy of the Florida population is not well understood.

Immature eagles from Florida migrate northward, primarily along the coast, in late spring and early summer (Broley 1947). Visual sightings of color-marked birds and band returns from eagles hatched in South Carolina suggested a coastal route to the Chesapeake Bay and then movement to Maine or the Great Lakes (Murphy et al. 1986). A secondary route may follow the Appalachian Mountains. Summering areas for southern eagles range from the Carolinas (Chester et al. 1990), through the Chesapeake Bay (Buehler et al. 1991b) to Canada's Maritime Provinces and the Great Lakes (Broley 1947, Stocek 1985). Specific areas along the migration corridor serve as stopover points or endpoints for migratory eagles. These areas may play a significant role in the life history of Southern bald eagles. Although

northward migration pathways and some destinations are known, the timing of migration and age-specific differences remain largely unknown. Few data were available for return (southward) migration to Florida.

Gerrard et al. (1978) found that some subadult Saskatchewan eagles marked as nestlings returned to the lake where they fledged. Observations of marked eagles establishing territories near their natal area in Saskatchewan suggests a return of breeding age birds to natal areas (Gerrard et al. 1980). Immature bald eagles tended to move farther from the nesting region than subadult and adult bald eagles (Hodges et al. 1987, Stalmaster 1987). In contrast, Gerrard et al. (1978) found that in Saskatchewan older immatures may migrate away (south) from an area first, or migrate faster and farther than 1 year olds. In areas where breeding densities are high (eg. Alaska and Florida), adults may remain near nesting areas through the non-breeding season to retain possession of their nesting territories or to be in position to move into a vacant territory (Hodges et al. 1987, W. Robertson, pers. commun.), as is common for many avian species that exhibit partial migration (Gauthreaux 1982).

Eagles tagged with radio-transmitters permit repeated locations of a bird over several years, rather than a single location when a bird dies and is recovered. Consequently, I used radio-telemetry to address the following objectives:

1) Determine the timing of migration (arrival and departure dates) and examine relationships with temperature, precipitation, water levels, and fish abundance.
2) Examine migration dates for age-specific and sex-specific differences.
3) Identify summering areas for Florida eagles.
4) Quantify the age-specific and sex-specific differences in migration distance.

Methods

Arrival and departure dates from fall 1987 to spring 1991 on the study area were determined for 18 eagles radio-tagged as nestlings in north-central Florida. Radio-tagged eagles rarely located on the study area were excluded from these analyses. Banding and radio-tagging procedures are discussed in detail in Chapter 2. While any radio-tagged eagle was on the study area, I tracked approximately once per week from a Cessna 172. I continued to radio-track approximately once every 3 weeks when no radio-tagged birds were on the study area to document their absence during the summer months. Beginning in early September, I again radio-tracked approximately once per week to determine arrival dates on the study area.

Locations from outside of Florida were compiled from recoveries of dead banded birds, sightings of marked birds, and radio locations of eagles carrying radio transmitters. Requests for information on marked eagles were mailed to the Hawk Migration Association of North America, USFWS Cooperative Research Units, Audubon Society Chapters, and many individuals and researchers in the eastern United States. Researchers in South Carolina, Chesapeake Bay, New York, Maine, and New Brunswick monitored the radio frequencies used for eagles marked in this study.

I used analysis of variance to test for differences in arrival dates, departure dates and number of days gone from the study area for sex, age, and year. I also used analysis of variance to examine migration distance in relation to sex and age. The Waller-Duncan K-ratio t-test was used in multiple comparisons to determine where differences occurred. I examined timing of migration in relation to water temperatures, air temperatures, precipitation, water levels, and fish abundance. See Chapter 2 for sources of data.

Results

All radio-tagged eagles migrated away from the study area during the summer. The latest date one was located on the study area was 7 July. The earliest that a radio-tagged young returned was 14 September. However, an unmarked subadult was observed in August during a boat survey of the shoreline on Newnans Lake.

Timing of migration

There was no difference between years ($F = 1.37$, $\underline{P} = 0.27$) or sexes ($F = 2.02$, $\underline{P} = 0.16$) in the dates radio-tagged young arrived on the study area in the fall (Table 3-1). There was, however, a significant difference in arrival dates by age ($F = 7.94$, $\underline{P} = 0.0003$) (Table 3-1). The Waller-Duncan multiple comparison test showed that 1-year old eagles (i.e. young fledged the previous spring) returned to the study area significantly later than individuals from older age classes. A wide range in arrival dates occurred for the 1 year age class. The earliest arrival date was similar for all 4 age classes of eagles (mid-September). The latest arrival dates varied considerably and were much later for 1-year old eagles.

Departure dates for the 3 year age class were slightly earlier than for the other age classes, but the difference was not significant ($F = 2.23$, $\underline{P} = 0.10$) (Table 3-1). There was no significant difference in departure dates by sex ($F = 2.62$, $\underline{P} = 0.11$), although females left on average 18 days later than males. There also was no significant difference by year ($F = 1.32$, $\underline{P} = 0.28$), although eagles tended to leave somewhat earlier in each successive year of the study. The latest departure dates in 1990 and 1991 were approximately 1 month earlier than in 1988 and 1989, and the earliest departure dates also were earlier in 1989, 1990 and 1991, probably related to the drought. During the course of the study, water levels dropped on all of the major lakes on the study area (Figure 3-1); many wetlands including Alachua Lake became completely dry. In 1989, declining water levels probably concentrated fish in

smaller pools; by 1990, water levels were so low that fish availability undoubtedly was reduced.

Since individuals in the 1 year age class tended to arrive on the study area somewhat later in the fall, they were gone from the study area for a somewhat longer time period during the summer (Table 3-2). There was, however, no significant difference by age ($F = 0.80$, $\underline{P} = 0.50$) or sex ($F = 0.45$, $\underline{P} = 0.50$) in the number of days individuals were gone from the study area during the summers of 1987 through 1990.

Only 3 individuals did not return to the study area until their second ($n = 2$) or third ($n = 1$) year. The maximum amount of time away for these 3 birds was 843 days; the minimum was 590 days. All other eagles returned to the study area each year.

Subadult eagles tended to migrate away from the study area when water levels were declining (Figure 3-1) each year of the study except 1991. In January and February 1991, unusually high rainfall increased water levels in area lakes. Precipitation (Figure 3-2) did not appear to be correlated with migration dates.

Departure dates from the study area seemed to correlate with maximum weekly temperature. The majority of radio-tagged birds left the study area before temperatures exceeded and remained above 30°C (Figure 3-3). Earliest arrival dates on the study area occurred after maximum temperatures dropped below 30°C.

I assumed that arrival and departure dates during the 4 years of this study were representative of other years to allow comparision of fish abundance for Newnans Lake in 1985 and 1986 (Edwards 1987) with mean arrival and departure dates for subadult eagles from this study. Eagles tended to arrive on the study area in the fall when fish abundance was low (Figure 3-4). Waterfowl are available from November through March with peak abundance occurring in January. This prey resource undoubtedly compensates for the low

fish availability at this time. Several subadult eagles initiated migration in the spring when fish abundance was at its annual peak (Figure 3-4).

Long-distance movements

I obtained locations outside of Florida for 29 subadult eagles; 23 of these had radio-transmitters (Table 3-3, Figure 3-5). All but 1 location south of the Chesapeake Bay and most of the locations north of the Bay were coastal. Birds located in Pennsylvania, New York, and just west of the Bay appeared to have followed major river systems or a chain of the Appalachian Mountains. It is unknown what routes were taken by the 4 birds located in the Midwest. Three of these locations occurred in 1990.

One radio-tagged eagle (165.942) returned to the same general area each summer from 1987 to 1990. The area was not checked in 1991. It was located near the coasts of northern Maine and southern New Brunswick between 28 June and 23 September each year (Table 3-3). Three of the locations were within 60 km of each other; 2 were within 15 km, but all 3 occurred in different years.

Subadult eagles in this study migrated up to 2,403 km north of their natal area (Table 3-4). For these analyses, I used the farthest location for each individual at each age. The mean maximum distance north that birds were located did not significantly vary by sex ($F = 0.32$, $P = 0.58$) or age ($F = 2.47$, $P = 0.09$). There was no interaction between sex and age ($F = 0.50$, $P = 0.69$). The farthest known summering areas for Florida eagles were Prince Edward Island and Quebec, Canada. The closest known summering area was on the South Carolina coast, where one bird (165.081) resided more than a month in 1988.

Radio-tagged eagles appeared to move north in the spring fairly rapidly. Data for 1-year-old eagles indicated rapid movement northward (Table 3-5). The most rapid movement for an individual was 1,081 km in a maximum of 5 days (216 km/day). At least 5 individuals moved more than 100 km per day.

Discussion

Florida eagle populations are partial migrants with non-breeding subadults migrating to northern latitudes during summer. Breeding adults probably do not migrate; many are observed in Florida during summer months. Observations of bald eagles in adult plumage at hawk migration counts probably are subadults that have attained adult plumage but are not yet breeding. Because I radio-tracked known-age eagles, I was able to determine at what age adult plumage characteristics are expressed. Birds 3 1/2 years of age showed considerable white coloration in the head and tail. The dark osprey-like stripe through the eye and some dark coloration in the tail was visible when these birds were in close proximity. They reached adult plumage at about 4 years of age. One 6-year-old eagle that migrated had not begun breeding.

Most subadults returned to Florida each fall, although 3 individuals remained away from Florida for 2-3 years, similar to other species of partial migrants (Gauthreaux 1982). One-year-old eagles returned to the study area significantly later than individuals from older age classes. Gerrard et al. (1978) similarly found that first-year birds lagged behind older birds on their return (northward) migration to Saskatchewan. I did not find any differences in incidence or distance of migration for the sexes.

Several explanations for summer migration of subadult Florida eagles have been proposed. One explanation is that northward migration in late spring occurs in response to extreme summer heat and humidity. Most subadults left the study area before summer temperatures peaked. Summer temperatures in Florida often exceed 30°C; they rarely reach 34°C (Figure 3-3). Hayes and Gessaman (1980) documented thermal stress in raptors at 34°C. Adults frequently were observed during the summer months. I observed several on summer boat surveys and have received reports from reliable observers of adults on the study area during summer. One unmarked subadult was observed in August during a boat survey,

suggesting that eagles can withstand summer temperatures in Florida. However, heat stress occurs at lower ambient temperatures in birds when humidity is high (King and Farner 1961), suggesting that high summer humidity in Florida may be more stressful.

It is doubtful that eagles migrate entirely in response to declining food availability. Earliest migration occurred when waterfowl abundance had decreased and few remained on area lakes. The extent to which subadults used this prey base is unknown. Edwards (1987) showed that fish abundance on one of the major lakes in the study area reached its peak during the time most subadults left the study area (Figure 3-4). Water levels are dropping at this time (Figure 3-1), which should make fish prey more available for a short time by concentrating the prey in a smaller area, although prey availability will decrease eventually. Increasing water temperatures (Figure 3-6) also may cause fish to move into deeper water, again decreasing prey availability. Lowest water levels, and potentially lowest prey availability occurred when the latest subadults migrated. Although fish kills generally occur on Florida lakes in August and September, they usually occur infrequently and involve low numbers of fish (J. Estes, pers. commun.). Thus, these kills are an unpredictable prey resource and occur too late in the summer to prevent subadults from migrating.

The migration patterns of subadult Florida eagles are the same as conventional migrants; they travel north in spring and south in fall. Unlike other migrants, these eagles were raised in the south immediately prior to northward migration. Apparently bald eagles in Florida retain the typical migratory instinct of most migrants, but timing of breeding has been adjusted to take advantage of the more favorable weather and prey abundance conditions that occur in winter.

Frequent observations of adult bald eagles in summer indicate that they remain on or near breeding areas. Newton (1979) generalizes that adult raptors may spend a longer time on the breeding range to maximize their time for breeding. In addition, he noted that adults

have a competitive advantage when prey becomes scarce. Thus immatures are more likely to leave the area, as I observed in Florida subadult eagles.

Eagles radio-tagged as nestlings in Florida from this study arrived on the Chesapeake Bay from 19 April to 22 July (mean=6 June) and departed from 19 June to 17 October (mean=3 September; Buehler 1990). On their northward migration, Florida eagles often were located on the Chesapeake Bay only 1 time, indicating that they did not remain there long. On southward migration, the same individuals often were located several times (Table 3-3; D. Buehler, pers. commun.) indicating more leisurely movements south. Generally, these birds passed through the Chesapeake region quickly with the mean stay on the Bay being only 4.5 days (Buehler 1990).

Data suggest that subadult eagles are philopatric to summering areas. One individual in this study (165.942; Table 3-3) was located in the same general area of Maine during 4 consecutive summers. Eagles radio-tagged in this study consistently frequented 2 areas of the northern Chesapeake Bay (Buehler et al. 1991b). Gerrard et al. (1978) reported that a marked Saskatchewan eagle migrated to the same wintering area in 4 successive years.

Thus, migration data allow identification of important summering areas for Florida subadult eagles. Management plans can then incorporate provisions to ensure the protection of these areas from habitat alteration and human disturbance, or public acquisition. For example, the most significant summer concentration area in Virginia recently was acquired by the Nature Conservancy for transfer and later sale to the U.S. Fish and Wildlife Service (M. Byrd, pers. commun.). Several eagles marked in this study were observed using this area (M. Byrd, pers. commun.).

The U.S. Fish and Wildlife Service currently is reviewing the status of bald eagles in the lower 48 states to determine whether populations in any of the 5 recovery regions warrant downlisting from endangered to threatened status. Three recovery regions occur in the East

(northern, Chesapeake, and southeastern) and are used at various times of the year by southeastern eagles. Consequently, downlisting of eagle populations in the northern or Chesapeake regions could negatively impact southeastern eagles. Downlisting of northern eagle populations and the possible accompanying relaxation of habitat protection in northern states could reduce survivorship of young from Florida and other southeastern populations. Development is compromising habitat suitability for eagles on the Chesapeake (Buehler et al. 1991c) and in coastal Maine (Todd 1979), 2 areas eagles from this study are known to frequent.

Four of 6 known dead subadult eagles from this study were recovered during or after migration north of the study area (Figure 3-5). Three died within 4 months after banding. One flew into a powerline and was electrocuted; the cause of death for the other 3 was not determined. Given the fact that migration is physically demanding and hazardous, especially to young and inexperienced birds, it is particularly important that high quality habitat be protected along the migration route. Consequently, there is concern about the negative effects that the proposed downlisting may have on the survival of southern bald eagles.

Table 3-1. Timing of arrival and departure from the north-central Florida study area for 1 to 4 year old subadult bald eagles, fall 1987 to spring 1991.

	Arrival dates			Departure dates		
	n	$\bar{x}$	Range	n	$\bar{x}$	Range
Age (years)						
1	18	12/16	9/17 - 3/11	19	5/5	2/1 - 7/7
2	14	11/3	9/20 - 1/15	13	5/3	4/10 - 7/5
3	8	10/12	9/14 - 11/8	8	4/3	3/1 - 5/24
4	4	10/16	9/24 - 11/12	4	4/26	4/2 - 6/10
Sex						
F	15	11/18	9/14 - 3/11	16	5/9	4/2 - 7/7
M	27	11/11	9/17 - 2/25	28	4/21	2/1 - 6/28
Year						
1987-88	6	12/9	9/17 - 3/1	6	5/25	4/15 - 7/7
1988-89	7	11/15	9/25 - 1/5	7	5/2	2/1 - 7/5
1989-90	14	11/9	9/14 - 1/24	13	4/28	3/7 - 5/24
1990-91	17	11/12	9/24 - 3/11	18	4/18	3/1 - 6/10
Total	44	11/15	9/14 - 3/11	44	4/28	2/1 - 7/7

Table 3-2. Number of days gone from the north-central Florida study area for 1 to 4 year old subadult bald eagles, spring 1987 to spring 1991.

	Days gone			
	n	$\bar{x}$	SE	Range
Age (years)				
1	18	192	14.1	69-300
2	13	173	11.6	84-245
3	7	153	17.1	71-201
4	4	179	20.5	145-238
Sex				
F	15	167	15.1	71-300
M	27	184	9.0	69-275
Total	42	178	7.9	69-300

Table 3-3. Tracking history and out-of-state locations and recoveries of subadult bald eagles (March 1987 to June 1990). Locations are in Alachua and Marion counties study area, unless indicated otherwise.

Nest number	Radio frequency	Probable sex	Tracking history: Dates	Tracking history: Location
1987 Fledglings				
AL 7A	165.100	M	11/11/87	SE of study area
			2/8/88 - 5/18/88	
			10/11/88 - 4/14/89	
			10/16/89 - 10/20/89	
			2/6/90 - 3/7/90	
			6/28/90	S of Oromocto on St. Johns River, NB
			10/25/90 - 11/24/90	
			12/5/90 - 2/12/91	S of study area
			2/19/91 - 4/10/91	
LV 25	165.520	M	9/17/87 - 5/24/88	
AL 7A	165.616	M	none since 7/30/87	
AL 27	165.675	F	11/12/87 - 6/10/88	
			3/17/88	in SE Georgia
			3/20/88	near Gainesville, FL
			10/6/88	N Florida/S Georgia
			11/29/88 - 4/14/89	
			10/4/89 - 5/2/90	
			8/90	Lake Erie, OH (unconfirmed)
			9/24/90 - 10/25/90	N of study area
			10/31/90 - 4/22/91	
AL 35	165.718	F	12/1/87, 12/2/87	SW of study area past Otter Creek toward Gulf Hammock
			4/20/88	upper Chesapeake Bay
MR 108	165.861	F	10/15/87	upper Rappahannock River, 20 miles upstream from Chesapeake Bay
			11/12/87 - 7/7/88	
			7/25/88	upper Rappahannock River, Virginia
			10/20/88 - 4/23/89	
			5/3/89 - 7/5/89	SE of study area
			9/14/89	
			9/20/89	S on Lake Harris

Table 3-3 (cont.)

Nest number	Radio frequency	Probable sex	Tracking history Dates	Location
	165.861 (cont.)		10/16/89 - 1/15/90	
			1/17/90 - 5/24/90	mostly SW of study area
			10/31/90 - 6/10/91	about half SW of study area
AL 17C	165.881	F	9/17/87	N of Jasper, Georgia
			11/12/87 - 5/18/88	
			10/11/88 - 3/13/89	
			5/25/89	N Florida/S Georgia
			9/20/89 - 4/17/90	
			9/24/90 - 4/2/91	
AL 35	165.942	F	5/27/87	
			6/7/87	upper Chesapeake Bay, Aberdeen Proving Ground, MD
			9/23/87	northern ME, near New Brunswick
			10/15/87	lower Chesapeake Bay S of Potomoc River mouth
			11/20/87	lower Chesapeake Bay, James River
			3/1/88, 3/2/88, 4/15/88	
			8/18/88	Hog Island, Machias Bay, ME
			11/22/88	Potomac River
			12/7/88	James River, Virginia
			8/17/89	Machias River, town of Machias, ME
			10/28/89	Chesapeake Bay
			11/8/89	N of study area
			2/21/90	SE of Lake Monroe, FL
			4/9/90	N of study area
			6/28/90	Ross Isl., E of Grand Manon, NB
AL 33	165.958	F	7/7/87	died and recovered in Surf City, NC (flew into powerline)
AL 19	165.999	F	5/27/87	
			6/25/87	Potomac River, Westmoreland S.P., VA
			8/30/87	recovered dead, Cape Jouriman, NB
AL 39	-	M	2/4/91	recovered dead near Flemington, FL (hit by car)

Table 3-3 (cont.)

Nest number	Radio frequency	Probable sex	Tracking history: Dates	Location
PU 18	-	M	9/4/89	recovered dead near Rhinelander, Oneida Co., WI
VO 34	-	M	4/16/89	remains found near Rochelle, FL
Unidentified 1987 bird			6/23/88	Mongaup River, Forestburgh, Sullivan Co, NY
1988 Fledglings				
AL 15A	165.081	M	6/23 - 7/29/88	SC coast, Santee River
			9/29/88	N Florida/S Georgia
			11/8/88 - 1/24/89	S of study area
			3/16/89 - 6/28/89	
			9/20/89 - 5/8/90	mostly S and W of study area
			10/2/90 - 4/12/91	mostly S and W of study area
AL 10	165.145	F	1/5/89	near Crystal River
			1/15/90	
MR 107	165.155	F	6/17/88	
			6/22/88	mouth of Potomac River
AL 17B	165.180	F	died prior to fledging	
AL 14	165.212	F	died prior to fledging	
AL 40	165.241	M	7/4/88	
			10/25/90 - 12/5/90	
			2/9/91 - 3/11/91	
AL 40	165.262	M	7/17/88	W side Chesapeake Bay below Baltimore
AL 24A	165.418	M	8/24/88	Naudua Creek, VA, N of Bay Bridge/Tunnel
			9/5/88	near Easton, MD
			9/21/88	near Fredricksburg, VA
			11/29/88	N Florida?
			8/8/89 - 9/4/89	Chesapeake Bay
			2/11/90	Horseshoe Beach, FL
			2/24/90, 5/30/90	
			9/5/90	S James River, VA

Table 3-3 (cont.)

Nest number	Radio frequency	Probable sex	Tracking history Dates	Location
AL 24A	165.561	F	10/31/88	W of Aberdeen Proving Ground, MD
			1/17/89	Prospect Bay, MD
			3/20/89	Chesapeake Bay
AL 33	165.593	M	10/20/88	N Florida/S Georgia
			1/5/89 - 4/14/89	
			11/17/89 - 5/8/90	
			10/31/90, 2/3/91 - 3/11/91	
AL 32A	165.957	M	8/24/88	mouth of Patuxent River, Chesapeake Bay
			9/25/88 - 2/1/89	
			10/4/89 - 4/13/90	
			4/23/90 - 5/13/90	Rappahannock River, VA/MD (3 locations)
			10/2/90, 10/9/90	N of study area
			10/31/90 - 3/1/91	mostly S of study area
AL 32A	165.998	F	5/22/88	Susquehana River, Bradford Co., PA
Unidentified 1988 or 1989 bird (with patagial and transmitter)			7/12/89	Catfish Lake, Croatan N.F., Craven Co., NC
1989 Fledglings				
AL 33	164.197	M	none since 6/23/89	
AL 28C	164.399	F	5/11/89	
			2/12/91	SW L. Wauberg, far
AL 10	164.496	M	none since 5/26/89	
AL 40	164.738	M	5/19/89	
			12/30/90	S of study area
			2/5/91 - 3/1/91	S of study area
AL 26A	164.756	M	none since 5/3/89	
AL 28C	164.798	M	10/16/89 - 5/4/90	
			10/31/90 - 4/10/91	
AL 40	164.814	M	12/1/89 - 4/29/90	half of locations S of study area
			10/9/90 - 5/15/91	half of locations S of study area

Table 3-3 (cont.)

Nest number	Radio frequency	Probable sex	Tracking history Dates	Location
AL 1A	164.895	M	none since 6/28/89	
AL 24A	164.897	M	died prior to fledging	
AL 3B	165.210	M	6/11/89	Susquehanna River
			6/12/89	Chesapeake Bay
			10/4/89 - 10/16/89	S of study area
			11/17/89 - 5/4/90	
			6/26/90 - 9/21/90	Potomac River, Chesapeake Bay (6 locations)
			10/9/90 - 5/15/91	
AL 17A	165.698	M	12/14/89	SE toward Rodman Reservoir
			1/15/90 - 4/23/90	
			10/9/90 - 4/22/91	half of locations S and W of study area
AL 17A	165.755	M	12/1/89 - 5/2/90	
			5/4/90	far N of Newnans Lake
			7/26/90 - 9/5/90	Potomac River, MD/VA (4 locations)
			10/9/90	NW of Newnans Lake
			10/25/90 - 4/22/91	
AL 3B	165.933	M	8/17/89	Machias River, ME
			12/1/89, 12/14/89	S of study area
			1/15/90	W of study area
			1/24/90 - 5/8/90	
			10/31/90	N of study area
			11/24/90 - 4/22/91	
Unidentified 1989 bird			6/6/90 - 6/25/90	near Hillsborough River, Prince Edward Island (3 locations)
1990 Fledglings				
AL 7B	164.011	M	6/7/90 - 6/17/90	Smutty Nose Island, Isles of Shoals, NH
			10/14/90	Back Creek Neck, MD
			10/24/90	S James River, VA
AL 32A	164.033	M	10/3/90	York River, VA
AL 26A	164.666	F	9/9/90 - 9/10/90	Fletcher, Miami Co, OH

Table 3-3 (cont.)

Nest number	Radio frequency	Probable sex	Tracking history: Dates	Location
AL 32A	164.902	M	3/11/91 - 4/10/91	
AL 43	164.963	F	10/3/90	N James River, VA
AL 29A	164.969	F	7/4/90 11/19/90 - 4/12/91	Onslow Co., NC, on New River
AL 3B	165.570	M	10/31/90 2/25/91 - 6/10/91	NW of study area
AL 3B	165.580	M	5/26/90 5/30/90	 N of Waldo, FL
AL 1A	165.992	F	4/10/91	
MR 57	-	F	7/19/90	found dead in Sutton, Ontario
Unidentified 1990 bird (with patagial and transmitter)			1/3/91	Mattamuskeet NWR, NC

Table 3-4. Maximum distance (km) from the north-central Florida study area an individual was located at each age, spring 1987 to fall 1990. Within a variable, means with the same letter are not significantly different (Waller-Duncan K-ratio t-test).

Variable	n	$\bar{x}$		SE	Range
Sex					
F	18	1296	A	158.4	155 - 2355
M	15	1313	A	124.8	483 - 2261
Age					
1	23	1276	B	121.0	155 - 2403
2	7	1131	B	215.5	160 - 2125
3	4	1526	AB	285.1	976 - 2129
4	2	2207	A	54.7	2152 - 2261
Total	37	1313		97.5	155 - 2403

Table 3-5. Distance migrated (km) and speed of movements for radio-tagged bald eagles from north-central Florida during their initial migration, spring 1987 to fall 1990.

Frequency	Last date on study area	Location date	Kilometers	Speed (km/day)
164.011	5/20/90	6/7/90	1796	100
164.666	6/10/90	9/9/90	1174	13
164.969	6/21/90	7/4/90	727	56
165.081	5/11/88	6/23/88	483	11
165.155	6/17/88	6/22/88	1081	216
165.210	5/26/89	6/11/89	1240	77
165.262	7/7/88	7/17/88	1190	119
165.418	6/28/88	8/24/88	1040	18
165.933	5/26/89	8/17/89	2125	26
165.942	5/27/87	6/7/87	1217	111
165.957	5/6/88	8/24/88	1115	10
165.958	7/2/87	7/7/87	684	137
165.998	5/6/88	5/22/88	1254	78

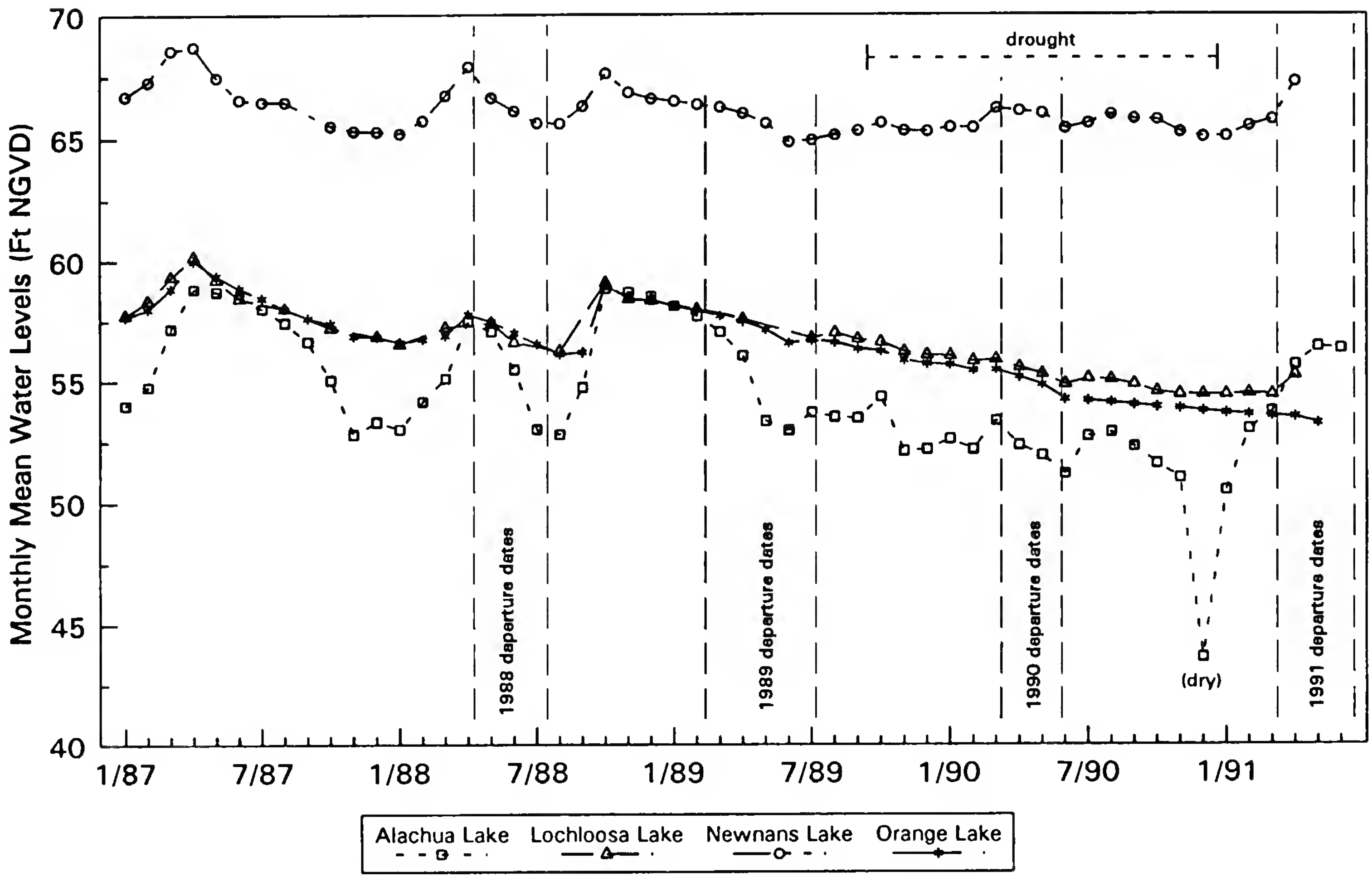

Figure 3-1. Mean monthly water levels (in feet NGVD) from January 1987 to June 1991 for Alachua, Lochloosa, Newnans and Orange lakes, Florida. Migration dates are for radio-tagged bald eagles 1 to 4 years of age.

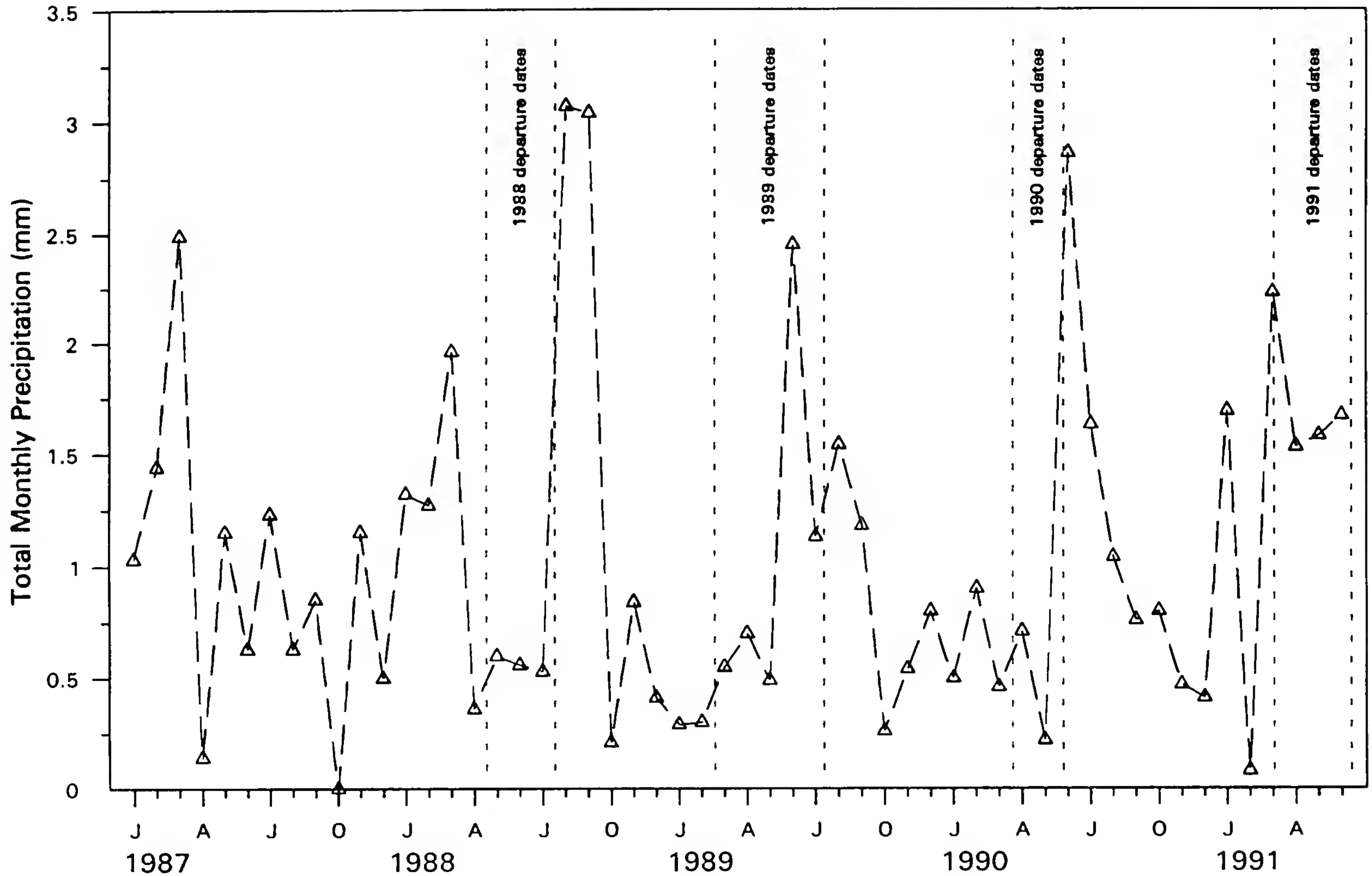

Figure 3-2. Total monthly precipitation (mm) measured at Gainesville Regional Airport from January 1987 to January 1991. Migration dates are for radio-tagged bald eagles 1 to 4 years of age.

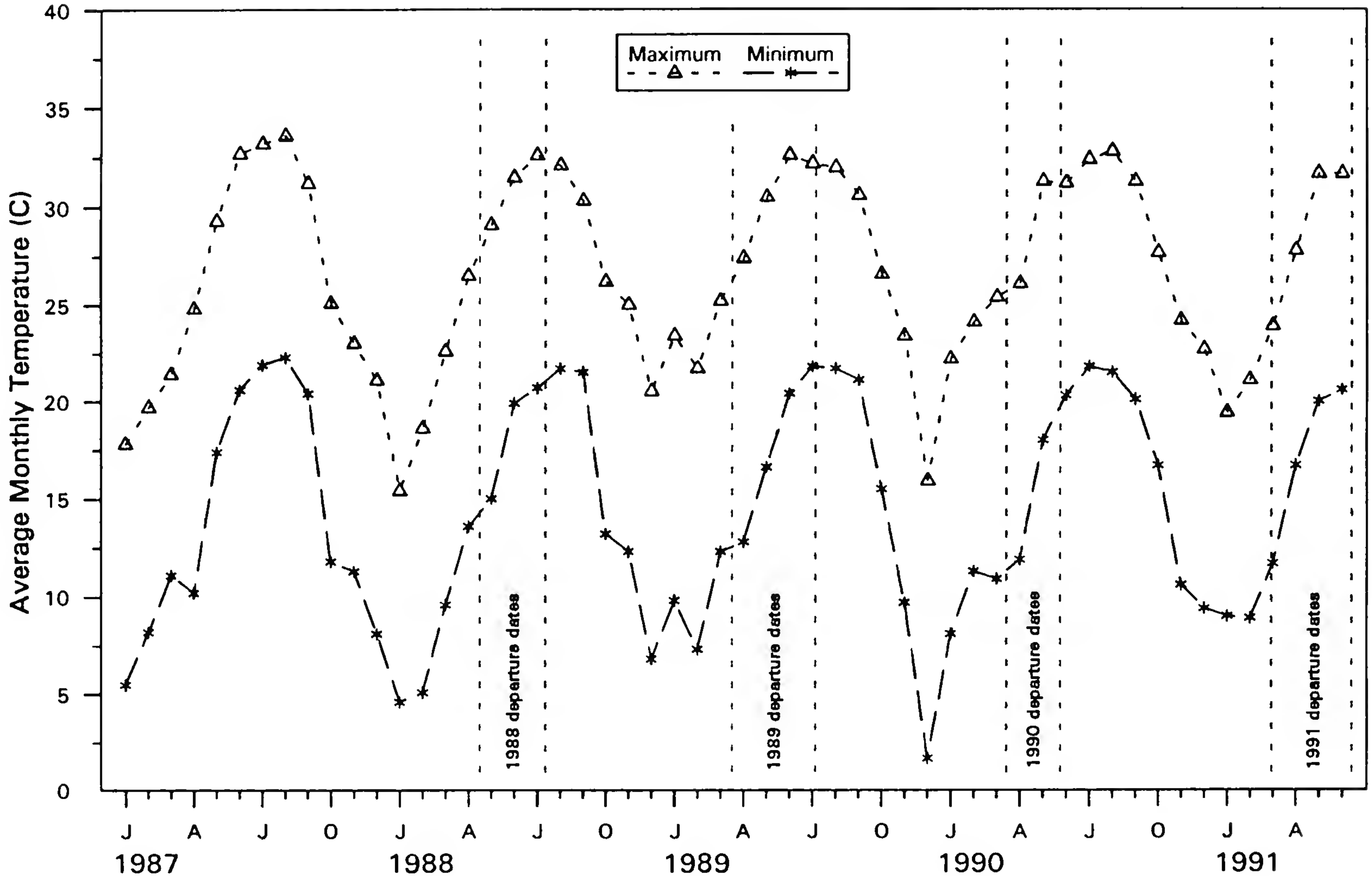

Figure 3-3. Average monthly maximum and minimum temperatures (°C) measured at Gainesville Regional Airport from January 1987 to January 1991. Migration dates are for radio-tagged bald eagles 1 to 4 years of age.

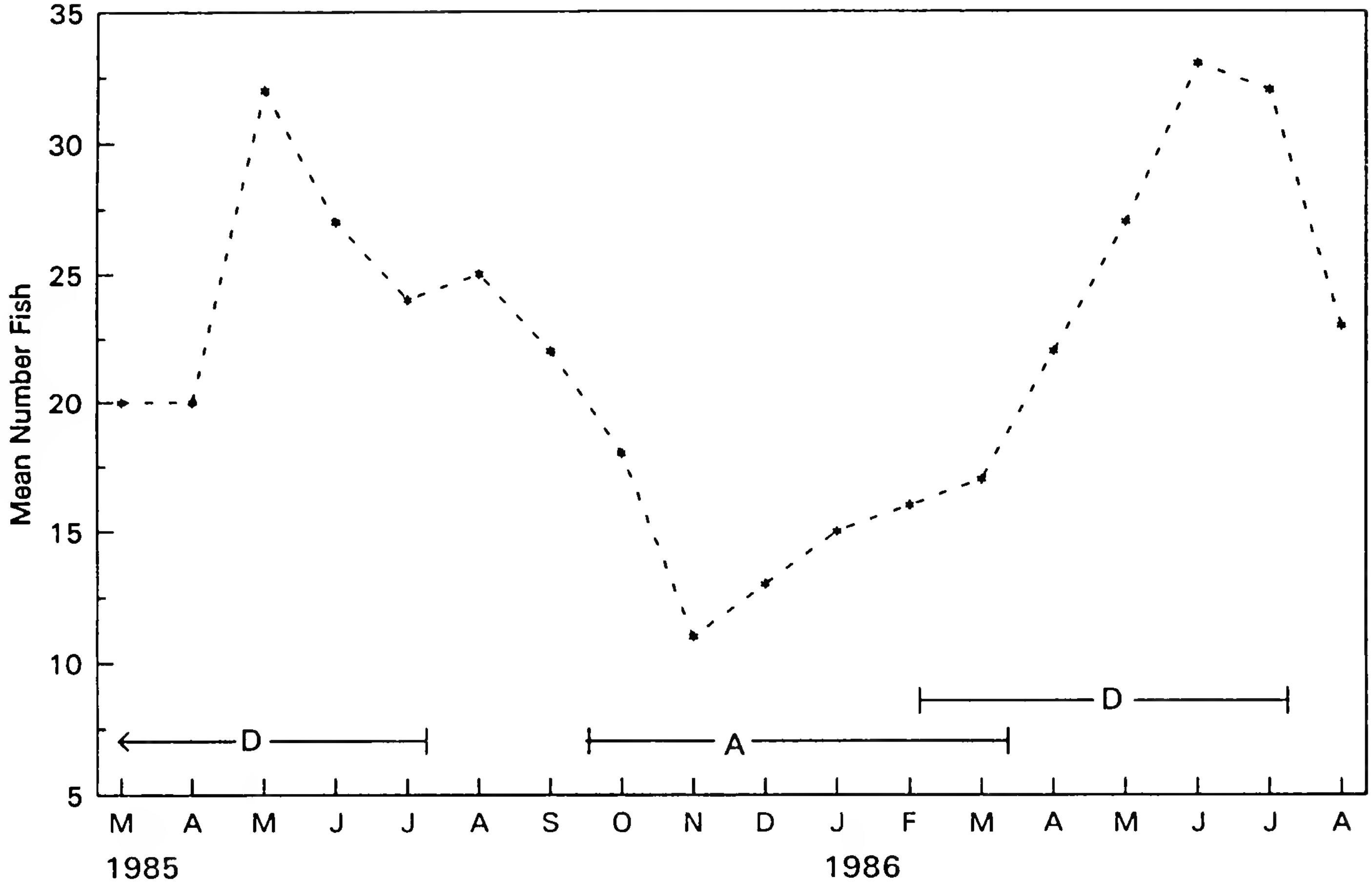

Figure 3-4. Mean number of fish electro-shocked on monthly transects on Newnans Lake (data from Edwards 1987) in relation to mean departure (D) and arrival (A) dates on the study area for radio-tagged 1 to 4 year old bald eagles.

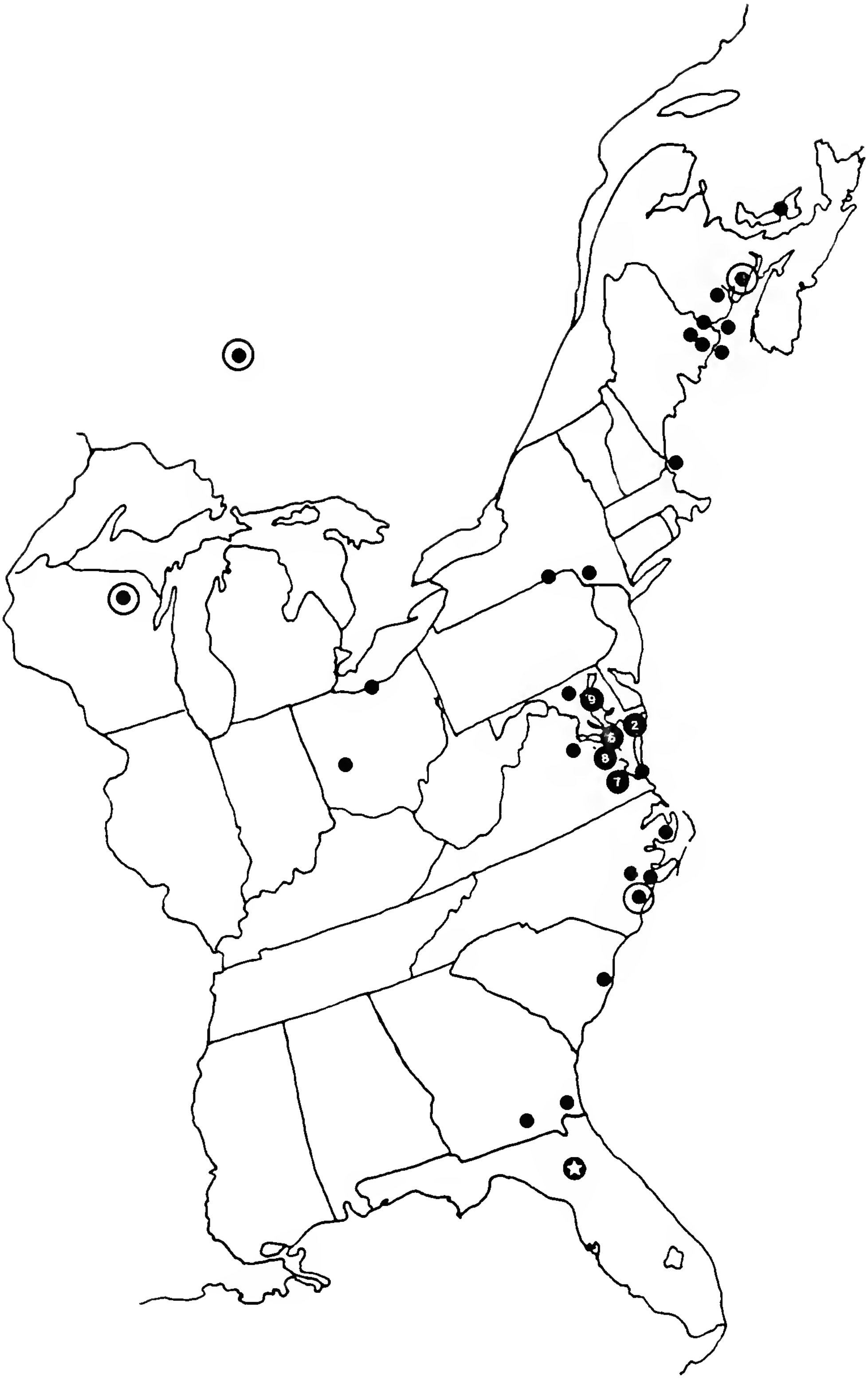

Figure 3-5. Locations of radio-tagged or marked bald eagles 1 to 4 years of age outside of Florida. Numbers indicate several locations; circled points indicate dead birds. Star indicates banding location.

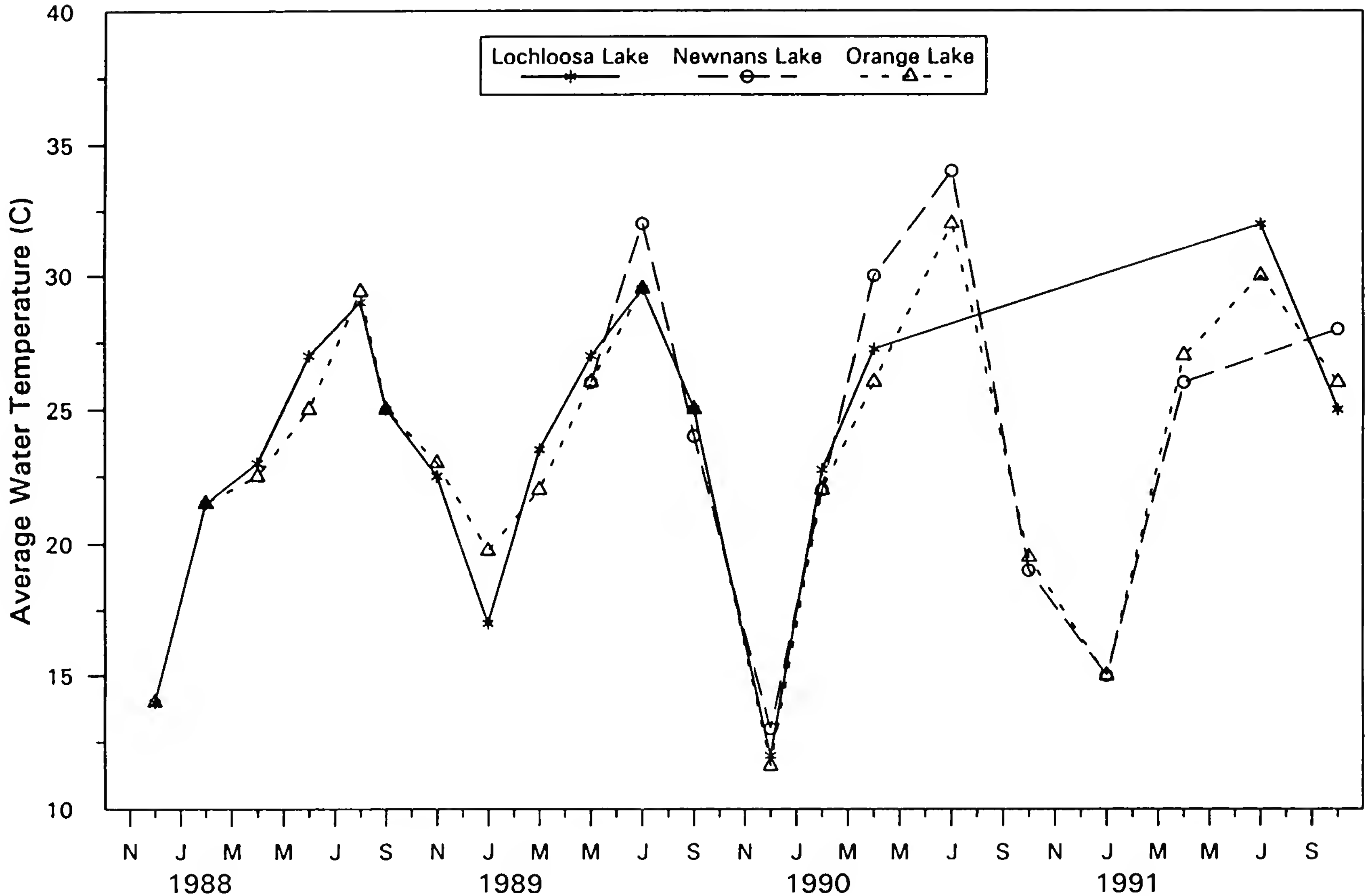

Figure 3-6. Water temperatures averaged from 4 sampling stations on Lochloosa, Newnans and Orange Lakes, 1988-1991 (unpubl. data, Florida Game and Fresh Water Fish Commission).

CHAPTER 4

MOVEMENTS AND HABITAT USE

Introduction

Identification of habitats important to Florida's eagle population is necessary to develop management guidelines, particularly since much of Florida is undergoing rapid development and recreational use of major lakes is increasing. The human population of Florida grew 27% between 1980 and 1988, and is projected to increase by an additional 20% by the year 2000 (U.S. Bureau of the Census 1990). Detrimental impacts on bald eagle populations have been documented. For example, although the overall number of breeding pairs has increased in Florida, eagle populations on the southwest coast have declined in numbers and productivity (S. Nesbitt, pers. commun). This area has undergone particularly rapid development; 62% of the 45 active nests in the area were on lands owned by development corporations, and 32% of 28 nests examined had urban development as the major land use in the secondary protection zone (Wood et al. 1989).

Habitat alteration, including disturbance at nest sites, is the most significant factor limiting recovery of eagle populations (U.S. Fish and Wildlife Service 1989). This includes cutting nest trees (Weekes 1974), logging and other human disturbance near nest sites leading to nest abandonment (Juenemann 1973), destruction of important perches and winter roosts (Stalmaster 1976, Stalmaster and Newman 1979, Hansen et al. 1981), and habitat losses to real estate development (Wood et al. 1989) or flood-control projects (Shapiro et al. 1982).

Shoreline development poses a particularly significant threat to bald eagle habitat. Eagles on the northern Chesapeake Bay tended to avoid developed shoreline areas (Buehler et

al. 1991c). Continued development of otherwise suitable habitat may limit use by eagles to areas with protected status, such as state and federal lands. Only 28% of 116 nests examined in Florida were on public lands; the majority (17%) were located on a single national forest (Wood et al. 1989). Concentration of eagles in these habitat islands would increase competition for limited food resources, nest sites, and roost sites. Public lands could not support the number of breeding pairs currently inhabiting Florida (601 in 1991; S. Nesbitt, pers. commun.). Although eagles may habituate to human activity and development, as have several nesting pairs in Florida, it is unknown how this affects their future survival and productivity, or if a nest will continue to be used once the habituated pair dies.

Currently, habitat protection zones are enforced around active bald eagle nests (U.S. Fish and Wildlife Service 1987) because it has been recognized that disturbance at nest sites can decrease productivity. Increasing productivity is not an effective management strategy, however, if immatures subsequently do not survive due to lack of adequate foraging, roosting, and loafing areas. At this time in Florida, there are no habitat protection measures aimed at foraging or roosting habitats that are important to non-breeding subadults, or to breeding adults. Furthermore, habitats important to the non-breeding eagle population have not been identified.

In this portion of the study, I identified age-related movement patterns, habitat use, and features of the environment that influence use of habitats by subadults. I addressed the following objectives:

1. Identify concentration areas for subadult bald eagles within the study area.
2. Examine philopatry to the study area and natal nest in relation to sex and age.
3. Examine frequency and occurrence of interactions between various age classes of eagles.
4. Determine habitat preference of subadult eagles in relation to sex and age.

5. Determine if locations of radio-tagged eagles differ from random locations on the study area, with respect to distance from various types of human disturbance (eg. developments and roads), occupied eagle nests, and various features of the environment.
6. Evaluate use of a GIS in the study of bald eagle habitat use.

Methods

Data on movements and habitat use of subadult eagles were collected primarily from eagles radio-tagged as nestlings in Florida (see Chapter 2). Some additional data were collected from southern eagles trapped and marked on the Chesapeake Bay. Radio telemetry is particularly useful in a study of movements and habitat use because it is possible to eliminate biases caused by differences in detectability of an animal in various habitats. It also is useful in relocating individuals that have moved long distances as eagles frequently do.

From September 1987 to June 1988, radio-equipped young were tracked twice weekly from the air using a single-engine Cessna 172 or 152, and periodically from a boat or truck. Beginning in fall 1988 and continuing throughout the remainder of the study, radio-equipped subadult eagles were tracked approximately once a week from the air. The majority of the locations were from aerial tracking. Aerial tracking minimizes the bias associated with frequent locations obtained in accessible areas when ground tracking (Samuel et al. 1985).

The pilot and an observer homed in on radio signals with a scanning receiver and H-type antennas (Telonics, Inc., Mesa, AZ) mounted on each wing strut. I attempted to pinpoint each signal on the study area to a specific location and obtained a visual location whenever possible. When it was not possible to obtain a specific location, a general location on the study area was recorded. Signals emanating from radio-tagged eagles off of the study

area generally were not followed due to time constraints, but a general direction was recorded.

Data recorded included date, time, location, activity, habitat, and association with other eagles. Eleven habitat types were defined on the study area (Table 4-1). Activity was recorded as perched, flying, or soaring. Flying birds were differentiated as such to indicate an association with the habitat in which they were located. Soaring birds were not associated with a particular habitat type. When possible, I also determined percent canopy cover class (0-25%, 26-50%, 51-75%, 76-100%) and perch location (canopy, supercanopy, edge of canopy, edge of supercanopy) for perched birds. Locations were plotted in the field on 1:2,000 aerial photographs or topographic maps. Location data were converted to Universal Transverse Mercator grid coordinates (Grubb and Eakle 1988) using 1:24,000 topographic maps.

I used the multiple response permutation procedure (MRPP) test (White and Garrott 1990) to determine if individuals changed their use of the study area in successive years. This non-parametric test makes no assumptions about the underlying distribution of the data, does not require equal sample sizes, and detects subtle changes in the distribution of an animal's locations. I had more than 1 year of data and large sample sizes ($n = 10$-53) on the study area for 7 individuals and small sample sizes ($n = 5$-10) for 4 additional individuals. I did not calculate home ranges because eagles wander widely and because White and Garrott (1990) suggest that tests on the actual data are preferable. I used analysis of variance weighted by individuals to examine sex and age differences in the mean distance subadults were located from their natal nest.

Habitat use as determined from telemetry locations was first examined for differences in sex or age by using multivariate analysis of variance (MANOVA) to test if the proportion of observations in the habitats differed for sex or age. I used arcsine transformation to assure

that the distribution of the data approximated a normal distribution (Sokal and Rohlf 1969:386-387). Habitats used infrequently were pooled with structurally similar habitats to assure that no more than 5% of the counts in each habitat were less than 5; this resulted in 6 categories. Developed habitat was available on the study area but never used by eagles and was excluded from sex and age analyses.

Habitat availability was measured from a geographic information system (GIS) data file (courtesy of the Office of Environmental Services, Florida Game and Fresh Water Fish Commission) that identified habitats on the study area from a Landsat satellite image with a resolution of 30 m^2. Nine habitat types were identified on the study area (Table 1-1). Of these, the sandhill habitat was rare and was never used by eagles. It was excluded from analyses.

Habitat preference was analyzed with a Chi-square goodness-of-fit test (Siegel 1956:42-47) comparing use and availability. The eleven habitats used on the study area (Table 4-1) were combined structurally into 8 categories and compared to the available 8 habitat categories measured from the Landsat image (Table 1-1). The Bonferroni z statistic was used to examine each habitat to determine which contributed significantly to the overall Chi-square statistic (Neu et al. 1974).

I also assembled a GIS data file containing all major and minor roads on the study area. Data from Alachua County was obtained courtesy of the Alachua County Department of Information Services. Additional roads on the study area outside of Alachua County were digitized from 1:24,000 topographic maps. The categories of roads I defined included city streets, county roads (which includes dirt roads and low-use paved roads), main roads (heavily used, paved, two-lane roads), and four-lane roads (four-lane and interstate highways).

All GIS data files were overlaid and analyzed using ERDAS (Earth Resources Data Analysis System) software. I measured the percent of each habitat type within 1-hectare and

10-hectare sized plots centered on each eagle location and on 300 random points. I also measured distances from eagles and random points to the nearest bald eagle nest occupied by a breeding pair, open water body greater than 0.4 ha in size, city street, county road, main road, four-lane road, and developed habitat. Distances to roads and development were used as indicators of tolerance to human disturbance. In addition, I determined the size of the nearest open water body greater than 0.4 ha in size.

To examine the effect breeding pairs had on the distribution of subadult eagles, I used analysis of variance on the distance individuals were located from nests occupied by a breeding pair in relation to age, sex, and month. Multiple comparisons were made with the Waller-Duncan K-ratio t-test.

To examine landscape level habitat preference, I used logistic regression on 19 variables (Table 4-2) to determine which characteristics differentiated between used and random locations following the model selection strategy suggested by Hosmer and Lemeshow (1989). Logistic regression is particularly useful when modeling a binary response variable (Hosmer and Lemeshow 1989) such as presence/absence. Locations (n=519) of perched and flying radio-tagged birds identified used areas. Locations of random points (n=300) in the study area were generated using a random number generator in SAS.

I initially included each variable in a univariate logistic regression model. Those variables with $\underline{P} < 0.25$ were included in a multivariate logistic regression model as potential variables for the final model. I examined all variables initially, even those correlated with each other, so as not to prematurely eliminate a variable that might be important. I then included the variables with $\underline{P} < 0.05$ in a reduced multivariate logistic regression model and compared the Akaike Information Criterion (AIC) values of the original and reduced models (Lebreton et al. 1992, Burnham and Anderson in press). Variables were added or deleted until the model with the lowest AIC was found. The lowest AIC results in the best

compromise between goodness-of-fit of the model and the cost of including an excessive number of variables in the model (SAS Institute Inc. 1990). The AIC is calculated as

$$AIC = -2 \log \text{likelihood} + 2(\text{number estimated parameters})$$

I used the same analyses to examine these variables in relation to sex and age. I restricted age-related analyses to age classes 1 and 2 because I had the most individuals in these 2 classes.

Results

From March 1987 to June 1991, I conducted 326 aerial surveys; I located 25 of the radio-tagged eagles on 306 of these flights. Excluding locations of nestlings and fledglings, I obtained 615 specific locations of radio-tagged subadult eagles and identified 118 general locations. I also received 250 signals that emanated from a location off of the study area but in Florida.

Movements

Individuals tended to wander on and off of the study area. As a crude index of philopatry to the study area, I compared the number of locations on and off of the study area for sex and age (Table 4-3). There was no interaction of sex and age ($F = 0.70$, $P = 0.56$) so they were examined separately. No differences were found by sex ($F = 1.90$, $P = 0.16$) or age ($F = 0.11$, $P = 0.96$). All eagles for which a specific location was obtained off of the study area, but in Florida, were north of Osceola and Polk counties (Figure 4-1).

Over the 4 years of the study, eagles tended to use portions of the study area more frequently than others (Figures 4-2 to 4-5). On Lake Lochloosa, 2 areas (Burnt Island and Allen's Point) were frequented by large numbers of eagles, both marked and unmarked. On Newnans Lake, radio-tagged eagles frequented Palm Point and the eastern shore of the lake. Several small lakes and wetlands on the study area were heavily used for short periods each

year. One wetland east of Lake Lochloosa was used by local commercial fishermen and hunters for disposal of waste fish parts; eagles frequented the area.

Of the 7 individuals with large sample sizes, 2 significantly altered their use of the study area in successive years ($\underline{P}$ < 0.05). One individual (165.675) was located on the study area for 4 years. Its use at age 1 was significantly different than at ages 2, 3, or 4 ($\underline{P}$ < 0.01). This resulted primarily from its frequent use of Lake Wauberg during 1988 (at age 1) that did not occur in subsequent years (Figure 4-6). The second individual (164.798) that changed its use of the study area used the southeastern portion of the study area during its second year (Figure 4-7). One of the 4 individuals with small sample sizes changed its use of the study area. At age 1, eagles tended to wander throughout the study area (Figure 4-7). At older ages, they restricted their movements to a smaller portion of the study area. Eagle 165.675, for example, restricted her movements primarily between Newnans and Lochloosa lakes.

Although 1- to 4-year-old females tended to be located farther from their natal nests than males, the difference was not significant (F = 2.06, $\underline{P}$ = 0.16) because of the high variation found among females (Table 4-4). This pattern is consistent with the general trend among birds for males to remain closer to the natal site. There was no difference between the age classes (F = 1.06, $\underline{P}$ = 0.38) and no sex/age interaction (F = 0.82, $\underline{P}$ = 0.21). The range for 1-year-old eagles, however, was larger than for the other age classes, indicating that this age class tended to wander throughout the study area.

Interactions

I observed 242 interactions of radio-tagged subadult eagles with all age classes of eagles, ospreys, and vultures. The interactions recorded included: chasing (5.8%), chased by (3.3%), perching together (35.5%), flying together (35.1%), located in the vicinity of (19.8%), and feeding with (0.4%). I observed a 2-year-old bird feeding with an adult. The

majority of the observations involved eagles perching or flying together and located in the vicinity of another eagle.

Of the 14 interactions with vultures, 10 observations were of eagles soaring with them, and 4 were eagles perched near vultures. Only 8 interactions with ospreys were observed; 2 of these involved an osprey chasing an eagle and 2 were an eagle chasing an osprey. Of the 120 interactions involving eagles where age class was identified, 46.7% of the locations of radio-tagged subadults were in association with adult eagles. Griffin and Baskett (1985) found that immature and adult eagles used overlapping foraging areas.

Perch characteristics

Perches used most often by subadult eagles were pine and cypress trees (Table 4-6). Four locations were of eagles perched in unused eagle nests; 3 sightings were 1- and 2-year-old birds. A 1-year-old eagle was located perched in an unused osprey nest.

Percent canopy cover was not different at perch sites used by males as compared to females (χ^2 = 2.97, $\underline{P}$ = 0.40). Overall, 48% were located at perches with 0-25% canopy cover, 2% at 26-50%, 9% at 56-75%, and 41% at 76-100% canopy cover.

I determined perch location (i.e. canopy, supercanopy, edge of canopy, or edge of supercanopy) for 224 locations of subadult bald eagles. The distribution of eagles perched in the 4 categories was not different for males and females (χ^2 = 4.66, $\underline{P}$ = 0.20). Overall, eagles were perched in the canopy on 16% of the observations, on the edge of the canopy (43%), in a supercanopy tree (30%), and on the edge of the supercanopy (10%).

Habitat use

There was no interaction between sex and age in habitat use (F = 1.05, $\underline{P}$ = 0.44), therefore sex and age were examined separately. Habitat use on the study area did not differ by sex (F = 0.49, $\underline{P}$ = 0.81) (Figure 4-9) or age (F = 0.70, $\underline{P}$ = 0.79) (Figure 4-10). Consequently, data were pooled in analyses of habitat preference. There was a significant

difference between habitat use and availability (χ^2 = 603.5, P < 0.0001). Marsh, open water, and hardwoods habitats were used in proportion to availability (Table 4-6). Cypress was used significantly more than expected, while all other habitats were used significantly less than expected (P < 0.05). The cypress habitat undoubtedly was used so frequently because of its location along most lake edges.

I compared the habitat composition of a 1 ha and 10 ha square plot around each location of a perched or flying eagle and found no difference (Table 4-7). The mean percent of each habitat was similar for both sized plots. Consequently I used only data for 1-ha sized plots in subsequent analyses. All habitats except developed comprised from 0% to 92% of the 1-ha plot. The low percentage of developed habitat in the 1-ha plot (0% to 40%) indicated avoidance of this habitat type.

The features of the landscape that discriminated between used and random points were distance to main roads (MAIN), water (WATER), nest (NEST) and developments (DEVEL), size of water (WATHA), and amount of developed (DEVL1), cypress (CYPR1), hardwoods (HDWD1), and marsh (MARS1) habitats in a 1 ha plot (Table 4-8). Eagle locations tended to be closer to water and nests, were nearer larger bodies of water, and had more cypress and marsh habitat within the 1 ha plot than random locations. Eagle locations tended to be farther from main roads and developed areas, and had less developed and hardwood habitat within the 1 ha plot than random locations. The addition of other variables to the reduced model resulted in an increase in the AIC, indicating that the reduced model was the most parsimonious for the data.

The relationship between time of year (month) and size of the closest body of open water was significant (F = 4.35, P = 0.001). All age classes of subadult bald eagles tended to be located closest to smaller water bodies during October, November, January, February, and March and nearer larger bodies of water in December, April, and May during the 4

years. Distance to the 3 largest lakes on the study area (Lochloosa, Newnans, and Orange) varied significantly by month ($F = 3.41$, $P = 0.0004$) and was greatest in October, January, February, and March.

The features of the landscape identified by logistic regression that differentiated between locations of males and females were distance to main roads (MAIN), county roads (CORD), all roads (ALLRDS), water (WATER) and eagle nests (NEST), and amount of developed (DEVL1) and marsh (MARS1) habitats (Table 4-9). However, examination of the data revealed that although these variables differed the most between the sexes, the actual differences were not large.

Comparisions of age classes 1 and 2 showed that distance to eagle nests (NEST) and development (DEVEL), size of water (WATHA), and amount of cypress (CYPR1) habitat differentiated between locations of individuals in these 2 age classes (Table 4-10). Birds in age class 1 tended to be closer to nests and developed areas, near smaller lakes, and had more cypress habitat in the 1 ha plot than those in age class 2. The largest difference occurred in distance to the nearest nest. Consequently, I examined distance to the nearest nest for all 4 age classes with analysis of variance.

Distance to the nearest nest occupied by a breeding pair of eagles varied significantly between age classes 1 to 4 ($F = 7.73$, $P = 0.0001$), but not by sex ($F = 1.19$, $P = 0.31$). There also was no interaction between age and sex ($F = 0.53$, $P = 0.71$). The Waller-Duncan K-ratio t-test revealed that birds in age class 1 ($\bar{x} = 1{,}711$ m) were located significantly closer to nests than older age classes (2: $\bar{x} = 2{,}357$ m; 3: $\bar{x} = 2{,}644$ m; 4: $\bar{x} = 2{,}774$ m). Distance to nests did not vary by month (November to June) ($F = 1.63$, $P = 0.12$).

Discussion

Movements

A concentration of locations on Lake Wauberg (Figure 4-1) occurred from 23 January to 22 February 1988, although eagles were located there in other months and years. Not only were all radio-tagged eagles located there, but many unmarked eagles as well. Up to 80 individuals used a roost near the lake during this time. This is a fairly small lake, 101 ha in size; however, a major gizzard shad (Dorosoma cepedianum) die-off occurred there during this time, resulting in an abundant but temporary food source. Following the fish-kill, eagles dispersed throughout the study area. Other temporally and locally abundant food sources on the study area have resulted in smaller concentrations of eagles. Additionally, subadult eagles were located closer to small lakes during most of the breeding season. Consequently, these smaller water bodies are also important to subadult eagles. In Minnesota, Fraser et al. (1985) also detected shifts of subadult eagles over a large area in response to temporally abundant food sources, and subadult eagles in Saskatchewan increased their use of small water bodies when spawning fish were available (Gerrard et al. 1990).

During 1988-89 few radio-tagged eagles returned to the study area. I believe that several subadult eagles may have wintered farther north because of the warm winter weather. The winter of 1988-89 was relatively mild on the Chesapeake Bay (D. Buehler, pers. commun.). One radio-transmittered bird (165.561; Table 3-3) was located on the Chesapeake Bay twice that winter, once in October and once in January, a time of year when southern eagles normally do not occur there (Buehler et al. 1991b).

After subadults returned to the study area, they continued to use the same general areas each year. The multiple response permutation procedure indicated that few birds changed their spatial use of the study area in subsequent years. They generally used areas near their natal nests ($\bar{x}$ = 19 km). Certain portions of the study area were used consistently

each year by large numbers of eagles. Thus, management for subadult populations must include protection and management measures aimed at these important concentration areas. Survival of subadults may be affected if a part of the area an individual uses becomes unsuitable. The bald eagle habitat management guidelines (U.S. Fish and Wildlife Service 1987) suggest habitat protection measures for important roosting, loafing, and foraging areas.

Habitat Use

Subadult eagles were not distributed randomly over the study area. Logistic regression analyses revealed that eagles tended to be located close to large water bodies and eagle nests, and were frequently in cypress and marsh habitats. Because most lakes on my study area are fringed with cypress, subadults likely preferred cypress because of its proximity to water. In other parts of Florida or the Southeast, other tree-dominated habitats near water might be preferred. Structural height diversity appeared important to subadults; 73% of perch locations occurred on the edge of the canopy or in the supercanopy. They avoided main roads and developed areas. Habitat management and protection measures must be aimed at areas that exhibit the habitat characteristics preferred by subadult eagles and that act as important loafing and foraging sites for subadult eagles. As human populations and lakeshore developments continue to increase, protected areas will become increasingly important to the subadult population.

A high proportion of dead eagles recovered in Florida were hit by cars (Wood et al. 1990). One of 2 known causes of mortality for birds in this study was collision with a car. The numerous roads and the increasing volume of traffic in Florida make this a significant problem that appears to be increasing. The close proximity of radio-tagged eagles to the 4 categories of roads on the study area further highlights the problem.

Subadults frequently were located near large lakes; however, distance to the 3 largest lakes was greatest when most eagle nests contain young chicks (January through March).

This may relate to temporal changes in prey availability or to greater aggression of nesting adults to subadult eagles near nests. Most eagle nests are located close to large bodies of water. Subadult eagles in age class 1 were located much closer to nests occupied by a breeding pair than were older subadults. One-year olds may be trying to maintain an association with adult bald eagles. Alternatively, adults may direct more nest defense behavior towards older subadults since 3 1/2-year-old individuals in this study had significant amounts of adult plumage. Gerrard et al. (1990) found that immatures tended to be farther from nests with eggs or young present.

Although subadults often frequented areas near eagle nests, they wandered over large areas. Thus, habitat protection around nests occupied by a breeding pair probably is not sufficient to also serve the habitat needs of subadults. The average distance subadults were located from nests was 2,055 m. As discussed in detail in Chapter 2, the boundary of the primary protection zone generally used in Florida is 229 m from a nest. Outside of the primary zone, there are few restrictions to habitat development.

Identifying the habitat requirements of nonbreeding eagles will provide the potential for improving remaining habitat or identifying potential future habitat. Both of these management practices will become increasingly important for mitigating loss of eagle habitat as eagle populations continue their post-DDT recovery (Grier 1982) and as human demands on the landscape continue their increase.

Use of a satellite image in a Geographic Information System (GIS) in this study of bald eagle habitat use allowed examination of various features of the landscape. Proximity analyses and habitat composition, for example, are measures that are extremely difficult and time consuming by hand, particularly when dealing with a large number of locations on a large study area. Thus, the GIS allowed more in-depth analyses of landscape habitat characteristics.

Table 4-1. Habitats used by perched, flying, and soaring eagles located on the study area in north-central Florida from fall 1987 to spring 1991.

Habitat	Total		Perched		Flying		Soaring	
	n	%	n	%	n	%	n	%
Clearcuts	22	3.6	10	2.7	5	3.4	7	7.9
Cypress	120	19.8	101	27.4	16	10.8	3	3.4
Developed	0	0.0	0	0.0	0	0.0	0	0.0
Hardwoods	95	15.7	76	20.7	12	8.1	7	7.9
Lake	72	11.9	3	0.8	47	31.8	22	24.7
Marsh	85	14.0	35	9.5	37	25.0	13	14.6
Palm Hammock	6	1.0	5	1.4	1	0.7	0	0.0
Pasture	24	4.0	7	1.9	6	4.1	11	12.4
Pasture with trees	59	9.8	41	11.1	12	8.1	6	6.7
Pinewoods	116	19.2	85	23.1	11	7.4	20	22.5
Woods	6	1.0	5	1.4	1	0.7	0	0.0
Total	605		368		148		89	

Table 4-2. Variables used in logistic regression analyses comparing used with random locations, sex, and age for bald eagles in north-central Florida from fall 1987 to spring 1991.

Variable	Description
	Distance (m) to nearest:
FORLANE	four-lane roads and interstate highways
MAIN	main roads (heavily used, paved, two-lane)
CORD	county roads (dirt and low-use paved roads)
CITY	city streets
ALLRDS	road of any type
DEVEL	developed habitat
NEST	bald eagle nest occupied by a breeding pair
WATER	open water body greater than 0.4 ha in size
WATHA	Size (ha) of nearest open water body greater than 0.4 ha in size
	Amount of each habitat found in a 1 ha square centered on each location:
SAND1	Sandhill and xeric oak scrub
PINE1	Pinewoods and mixed pine/hardwoods
HDWD1	Hardwoods (hammock, forest, and swamp)
CYPR1	Cypress
MARS1	Freshwater marsh and wet prairie
WATR1	Open water
GRAS1	Grassland with and without scattered trees
CLCT1	Clearcut with some shrub and brushland
DEVL1	Developed lands (includes roads)

Table 4-3. Mean percent of bald eagle locations on the study area in north-central Florida as an index of philopatry weighted for repeated locations of individuals, fall 1987 to spring 1991.

Sex	Age	n	wn[a]	$\bar{x}$(%)	SE	Range
F		356	21	68.3	8.1	0.0 - 100.0
M		513	32	69.8	5.4	0.0 - 100.0
	1	427	24	67.3	7.8	0.0 - 100.0
	2	259	17	69.6	7.8	0.0 - 100.0
	3	119	9	65.3	12.0	0.0 - 100.0
	4	69	4	70.6	4.3	61.9 - 81.8
F	1	180	9	60.7	15.7	0.0 - 100.0
	2	51	5	82.3	8.7	55.6 - 100.0
	3	68	4	65.5	23.2	0.0 - 100.0
	4	57	3	71.9	5.7	61.9 - 81.8
M	1	242	14	76.4	7.3	0.0 - 100.0
	2	208	12	64.3	10.3	0.0 - 100.0
	3	51	5	65.2	14.1	25.0 - 100.0
	4	12	1	66.7	-	66.7 - 66.7
Total		874	54	68.0	4.6	0.0 - 100.0

[a]Sample sizes weighted by individual.

Table 4-4. Mean distance (km) 1- to 4-year-old bald eagles were located from their natal nest in north-central Florida from fall 1987 to spring 1991.

Sex	Age	n	wn[a]	$\bar{x}$	SE	Range
F		269	17	27.5	9.2	0.7 - 571.4
M		332	29	13.9	1.3	0.3 - 155.8
	1	345	19	19.3	4.8	0.3 - 571.4
	2	158	14	12.8	1.9	0.5 - 171.7
	3	63	9	29.8	15.0	1.6 - 149.3
	4	35	4	14.1	0.5	2.5 - 40.4
F	1	160	6	27.0	14.4	1.4 - 571.4
	2	31	4	16.1	5.7	0.7 - 171.7
	3	48	4	49.3	33.4	1.6 - 149.3
	4	30	3	14.4	0.4	3.1 - 40.4
M	1	185	13	15.7	2.7	0.3 - 155.8
	2	127	10	11.5	1.5	0.5 - 40.8
	3	15	5	14.2	1.8	1.8 - 30.4
	4	5	1	12.9	-	2.5 - 23.4
Total		601	46	18.9	3.6	0.3 - 571.4

[a]Sample size weighted by number of individuals.

Table 4-5. Perch use (%) of radio-tagged eagles 1 to 4 years of age located in north-central Florida from fall 1987 to spring 1991.

	Sex		Age				
Perch	F	M	1	2	3	4	Total
Snag	7.0	3.9	5.3	2.3	11.1	8.3	5.3
Pine	32.5	30.6	33.9	29.6	22.2	33.3	31.4
Cypress	25.5	24.4	24.3	21.6	27.8	37.5	24.9
Hardwood	15.9	16.7	13.2	20.4	27.8	8.3	16.3
Palm	1.9	2.8	2.1	4.6	0.0	0.0	2.4
Eagle nest	2.6	0.0	1.1	1.1	0.0	4.2	1.2
Osprey nest	0.6	0.0	0.5	0.0	0.0	0.0	0.3
Ground	7.6	7.8	7.4	10.2	5.6	4.2	7.7
Tree	3.8	12.2	9.0	10.2	2.8	4.2	8.3
Shrub	0.0	0.6	0.5	0.0	0.0	0.0	0.3
Fencepost	2.6	1.1	2.6	0.0	2.8	0.0	1.8
n	157	180	189	88	36	24	337

Table 4-6. Comparision of use and availability of 8 habitats for subadult bald eagles in north-central Florida from fall 1987 to spring 1991.

Habitat	Observed	Expected[a]	95% CI	
CLCT	0.029	0.110	0.009 - 0.049	< *[b]
CYPR	0.241	0.041	0.189 - 0.292	> *
DEVL	0.0	0.081	0.000 - 0.000	< *
GRAS	0.127	0.180	0.087 - 0.167	< *
HDWD	0.170	0.127	0.124 - 0.215	=
MARS	0.139	0.125	0.097 - 0.180	=
PINE	0.199	0.270	0.151 - 0.246	< *
WATR	0.096	0.066	0.061 - 0.132	=
n	519	135,811		

[a]Expected proportions are based on habitat availability.
[b]< - use less than availability; > - use greater than availability; = - use equal to availability. Asterisks indicate observed significantly different than expected, Bonferroni z statistic ($\underline{P}$ < 0.05).

Table 4-7. Percent habitat availability in 1-ha and 10-ha plots centered on locations of radio-tagged eagles (n=519) in north-central Florida, fall 1987 to spring 1991.

Habitat	1-ha plot				10-ha plot			
	$\bar{x}$	SE	Minimum	Maximum	$\bar{x}$	SE	Minimum	Maximum
PINE	20.0	1.10	0	100	19.8	0.88	0	97
SAND	0.0	0.00	0	0	0.0	0.00	0	1
HDWD	9.6	0.83	0	92	9.6	0.62	0	71
MARS	14.7	1.02	0	100	15.0	0.86	0	100
CYPR	16.1	1.12	0	100	12.1	0.70	0	100
WATR	16.2	1.35	0	100	19.3	1.15	0	100
GRAS	9.5	1.04	0	100	10.0	0.91	0	100
CLCT	5.4	0.62	0	100	5.3	0.50	0	86
DEVL	1.3	0.22	0	40	1.7	0.20	0	30

Table 4-8. Comparison of used bald eagle locations and random points in north-central Florida for various features of the landscape using logistic regression, fall 1987 to spring 1991. Variables are defined in Table 4-3. All variables included in univariate analyses; variables with P < 0.25 included in full logistic regression model; variables with P < 0.05 included in reduced model.

Variable	Used $\bar{x}$	Used SE	Random $\bar{x}$	Random SE	Full model P[a]	Reduced model P[a]
FORLANE	3374.0	97.1	3890.0	186.7	0.16	
MAIN	1829.0	63.4	1457.0	77.1	0.0009	0.00001
CORD	488.0	16.3	476.0	26.0		
CITY	5309.0	110.5	5378.0	201.9	0.31	
ALLRDS	445.0	16.2	348.0	19.5	0.40	
DEVEL	456.0	17.4	323.0	21.5	0.21	0.01
NEST	2055.0	87.6	4306.0	179.3	0.00001	0.00001
WATER	475.0	28.9	1396.0	72.7	0.00001	0.00001
WATHA	1308.0	51.3	476.3	54.6	0.001	0.0005
PINE1	20.0	1.1	25.9	1.9	0.51	
HDWD1	9.6	0.8	14.0	1.5	0.58	0.05
CYPR1	16.1	1.1	3.0	0.6	0.31	0.00001
MARS1	14.7	1.0	9.3	1.3	0.47	0.06
WATR1	16.2	1.3	6.5	1.3	0.52	
GRAS1	9.5	1.0	18.9	1.8	0.52	
CLCT1	5.4	0.6	10.8	1.1	0.53	
DEVL1	1.3	0.2	6.2	1.0	0.80	0.0053
AIC					753.76	744.28

[a]Multivariate analyses

Table 4-9. Comparison by sex of bald eagle locations in north-central Florida for various features of the landscape using logistic regression, fall 1987 to spring 1991. Variables are defined in Table 4-3. All variables included in univariate analyses; variables with $\underline{P} < 0.25$ included in full logistic regression model; variables with $\underline{P} < 0.05$ included in reduced model.

	Female		Male		Full model	Reduced model
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\underline{P}$[a]	$\underline{P}$[a]
FORLANE	3255.0	136.8	3443.0	137.6	0.75	
MAIN	2049.0	104.0	1629.0	79.4	0.005	0.0008
CORD	453.0	22.8	523.0	24.0	0.008	0.01
CITY	5463.0	162.4	5100.0	152.1	0.76	
ALLRDS	430.0	22.4	462.0	24.2	0.02	0.03
DEVEL	431.0	22.7	485.0	26.8	0.30	
NEST	2104.0	127.8	2014.0	121.1	0.10	0.07
WATER	517.0	44.9	431.0	38.9	0.04	0.09
WATHA	1308.0	76.6	1317.0	72.2	0.89	
PINE1	21.3	1.7	18.1	1.4	0.24	
HDWD1	9.7	1.3	9.8	1.1	0.23	
CYPR1	16.6	1.7	15.3	1.6	0.24	
MARS1	13.3	1.5	16.5	1.5	0.25	0.09
WATR1	15.9	2.1	17.1	1.8	0.24	
GRAS1	8.9	1.5	10.0	1.5	0.25	
CLCT1	5.7	1.0	5.1	0.8	0.25	
DEVL1	1.9	0.4	0.8	0.2	0.16	0.007
AIC					621.06	603.11

[a]Multivariate analyses

Table 4-10. Comparison of bald eagle age classes 1 and 2 for various features of the landscape using logistic regression, north-central Florida, fall 1987 to spring 1991. Variables are defined in Table 4-3. All variables included in univariate analyses; variables with P < 0.25 included in full logistic regression model; variables with P < 0.05 included in reduced model.

Variable	Age 1		Age 2		Full model	Reduced model
	$\bar{x}$	SE	$\bar{x}$	SE	P[a]	P[a]
FORLANE	3249.5	133.3	3520.6	179.1	0.30	
MAIN	1671.0	67.8	1949.4	149.8	0.34	
CORD	462.2	20.1	547.9	37.2	0.07	
CITY	5191.7	147.9	5223.4	218.2	0.13	
ALLRDS	426.9	20.1	492.2	37.7	0.09	
DEVEL	433.3	20.2	535.3	44.7	0.10	
NEST	1723.3	98.4	2356.7	189.3	0.0009	0.00001
WATER	430.0	33.0	466.5	66.0	0.29	
WATHA	1228.0	67.2	1422.9	108.6	0.001	0.002
PINE1	19.0	1.4	17.7	2.0	0.01	
HDWD1	10.1	1.1	9.0	1.8	0.01	
CYPR1	17.3	1.5	13.6	2.1	0.01	0.13
MARS1	13.2	1.3	18.1	2.3	0.01	
WATR1	17.0	1.9	17.8	2.8	0.01	
GRAS1	9.9	1.4	9.3	2.1	0.01	
CLCT1	5.4	0.8	5.5	1.3	0.01	
DEVL1	1.0	0.2	1.3	0.5	0.01	0.01
AIC					490.16	479.01

[a]Multivariate analyses

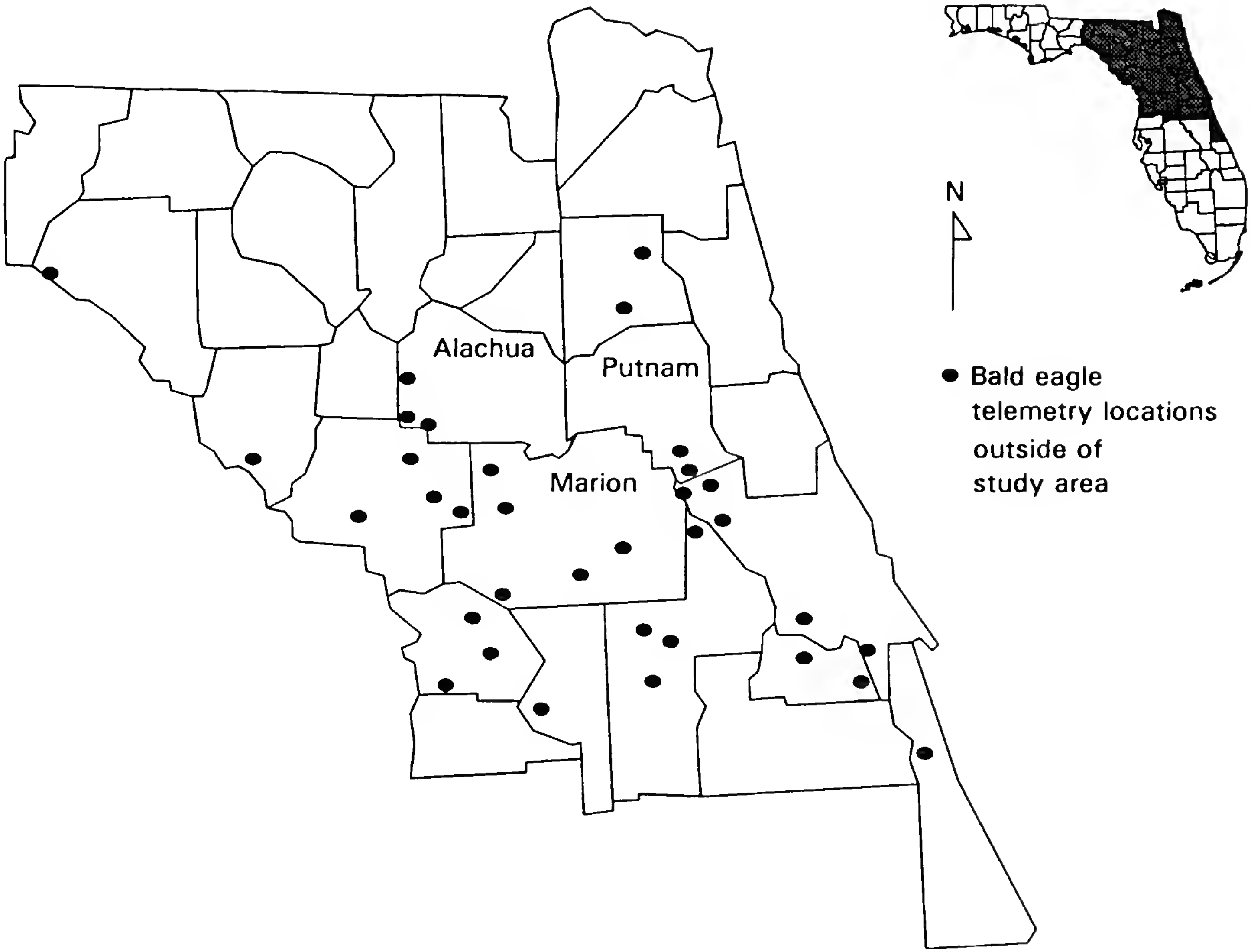

Figure 4-1. Bald eagle telemetry locations in Florida but outside of the study area in north-central Florida, 1987 to 1991.

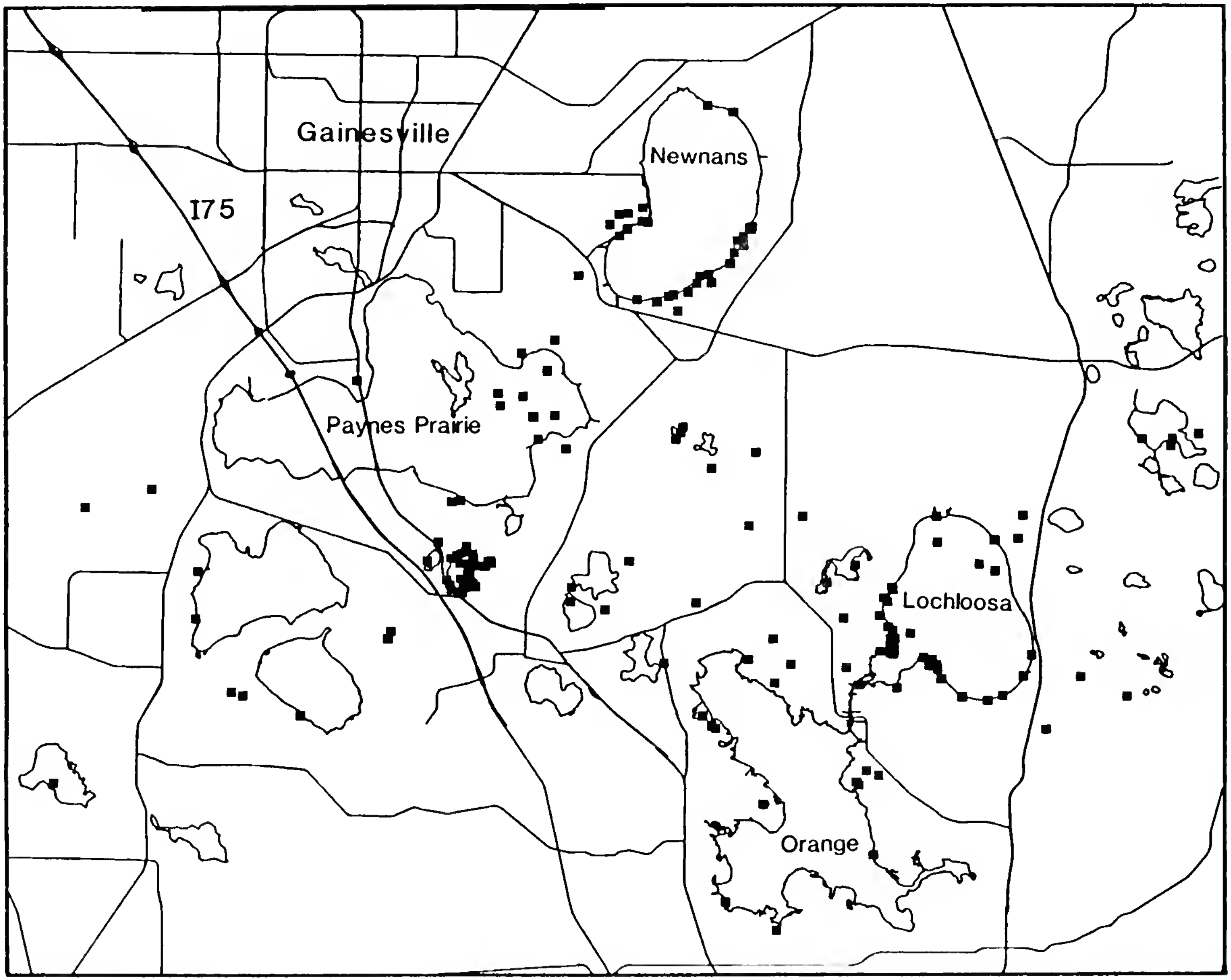

Figure 4-2. Telemetry locations of 1 to 4 year old bald eagles in north-central Florida from September 1987 to July 1988.

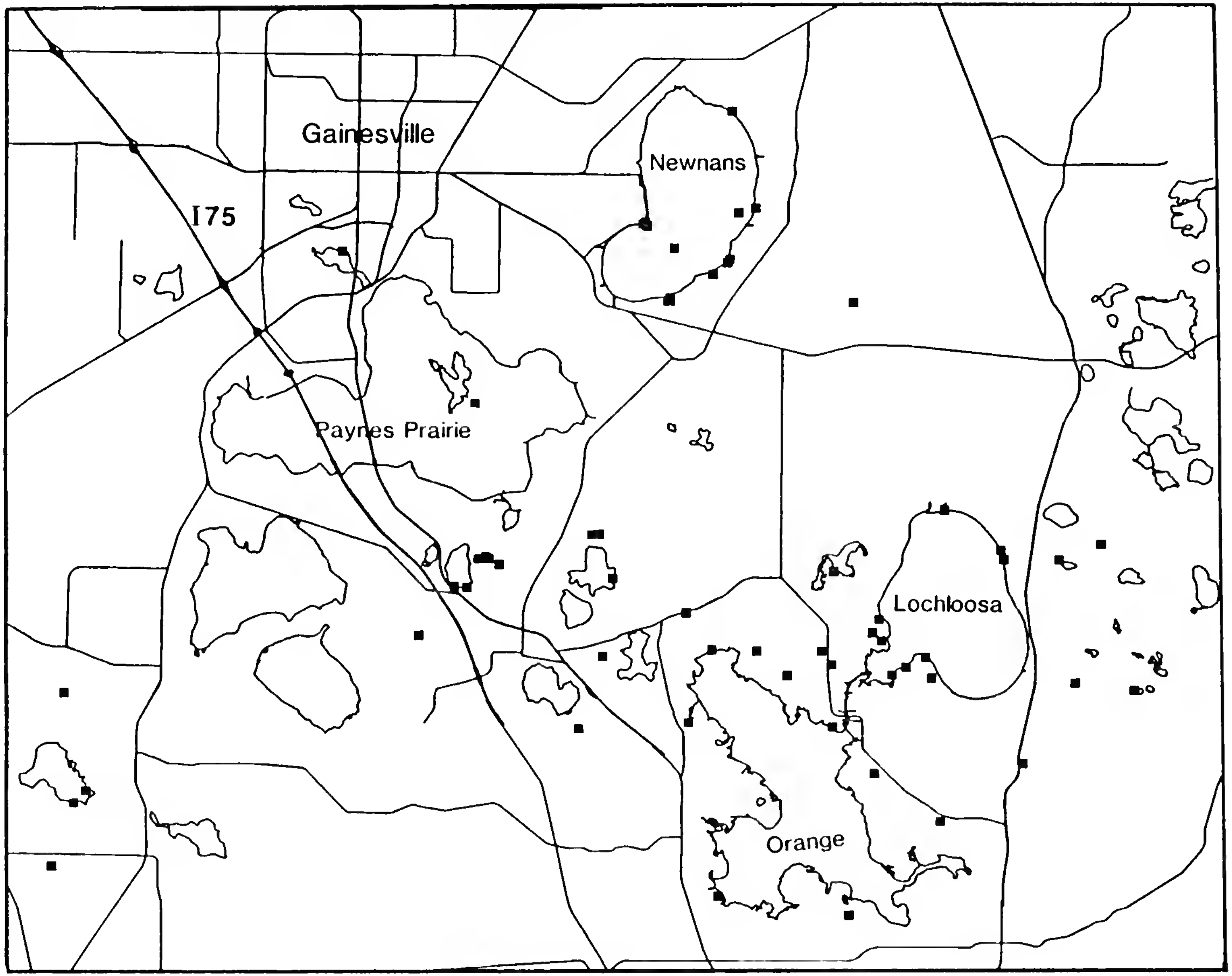

Figure 4-3. Telemetry locations of 1 to 4 year old bald eagles in north-central Florida from September 1988 to July 1989.

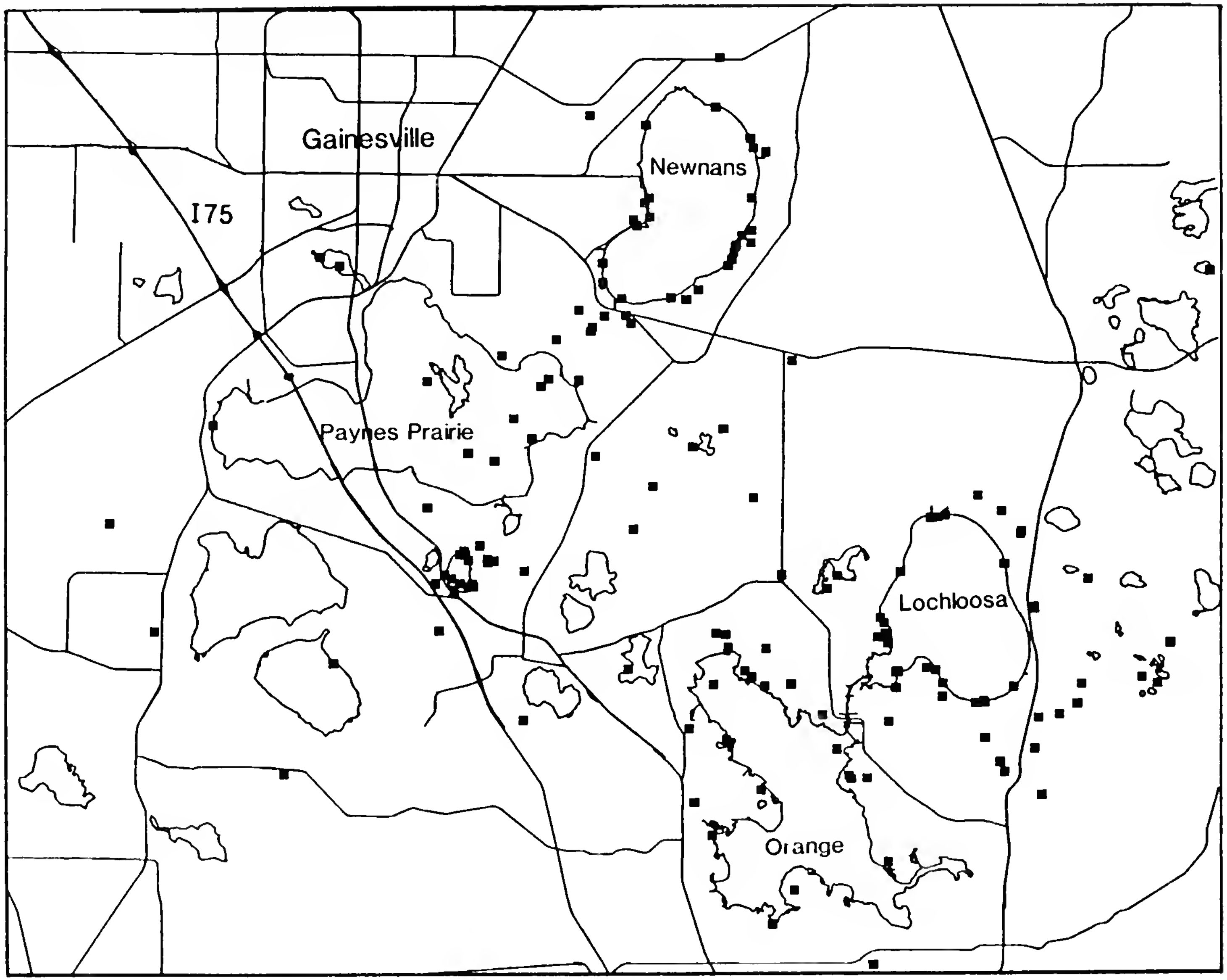

Figure 4-4. Telemetry locations of 1 to 4 year old bald eagles in north-central Florida from September 1989 to July 1990.

Figure 4-5. Telemetry locations of 1 to 4 year old bald eagles in north-central Florida from September 1990 to July 1991.

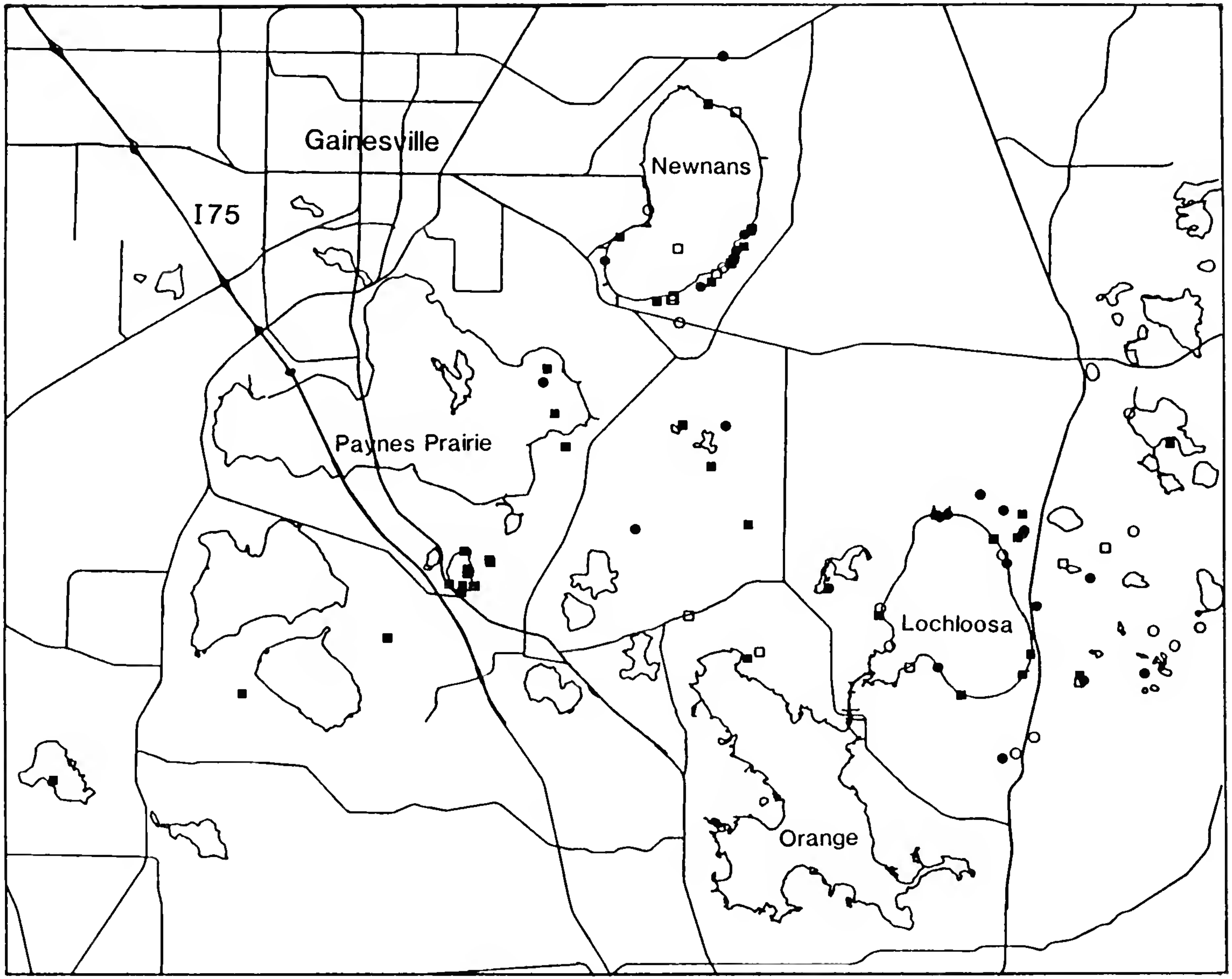

Figure 4-6. Telemetry locations in north-central Florida of subadult bald eagle 165.675 at 1 to 4 years of age, fall 1987 to spring 1991. Ages 1=closed rectangle, 2=open rectangle, 3=closed circle, 4=open circle.

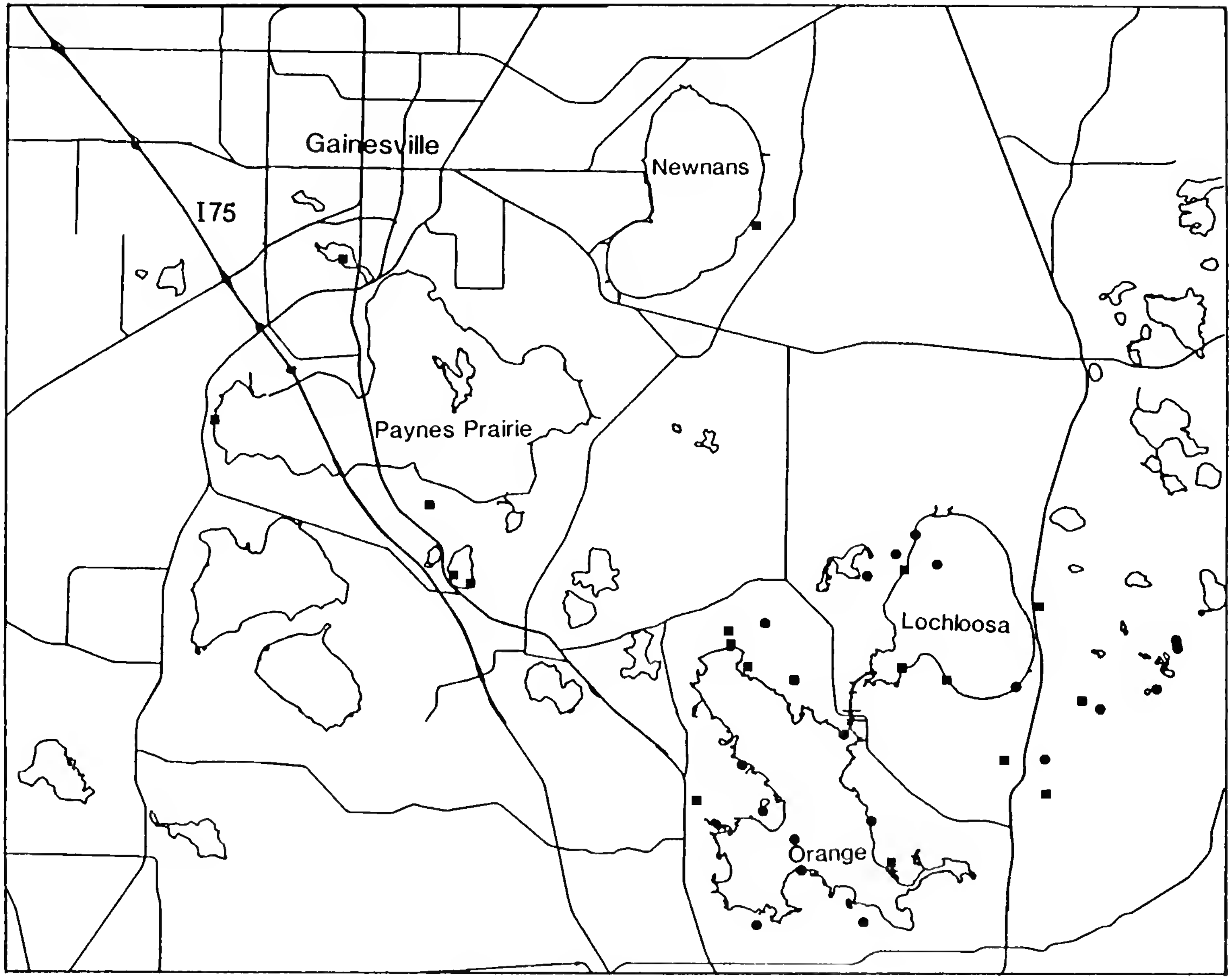

Figure 4-7. Telemetry locations in north-central Florida of subadult bald eagle 164.798 at 1 and 2 years of age, fall 1989 to spring 1991. Ages 1=closed rectangle, 2=closed circle.

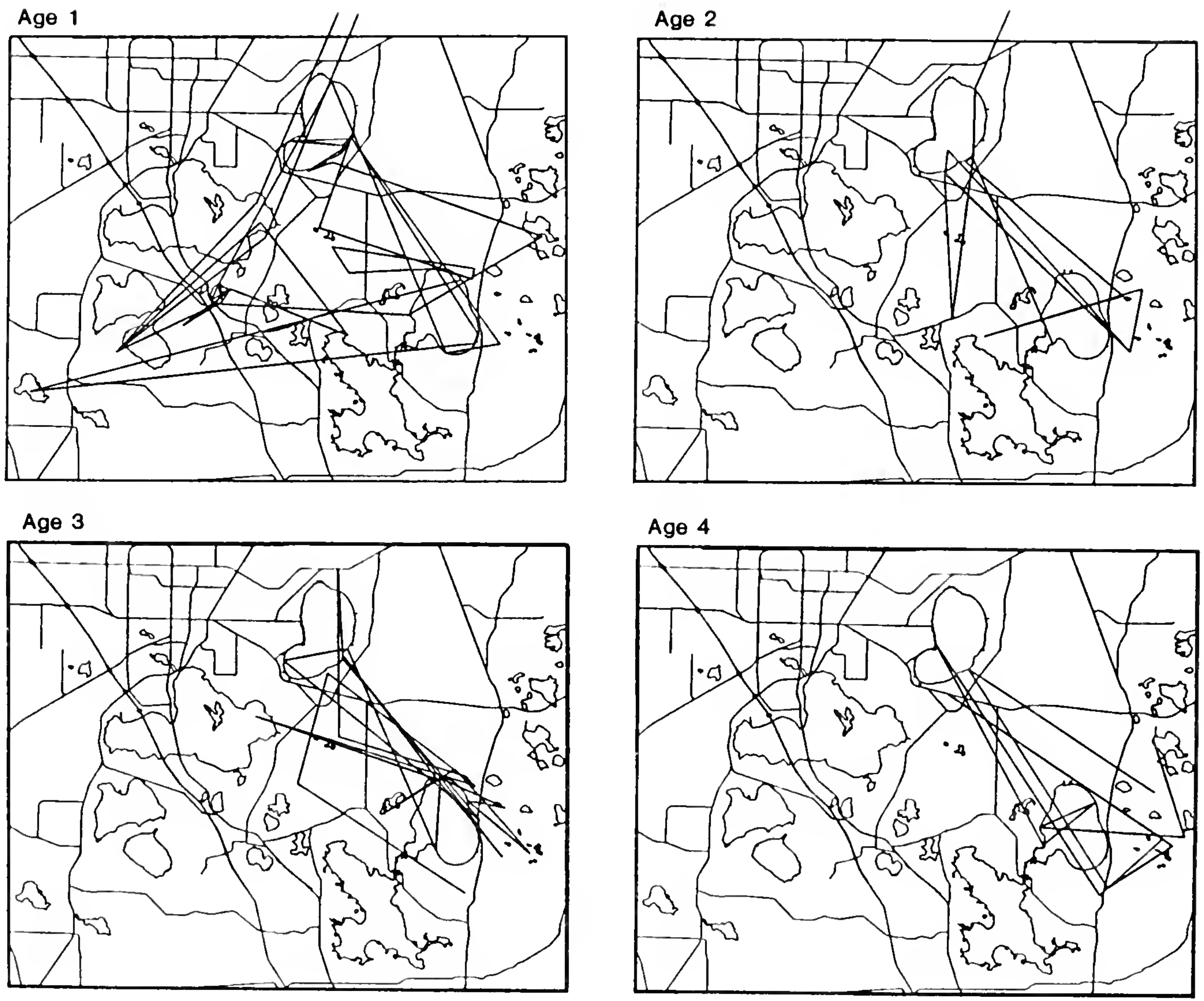

Figure 4-8. Consecutive radio locations of eagle 165.675 from 1 to 4 years of age on the north-central Florida study area, 1987 to 1991.

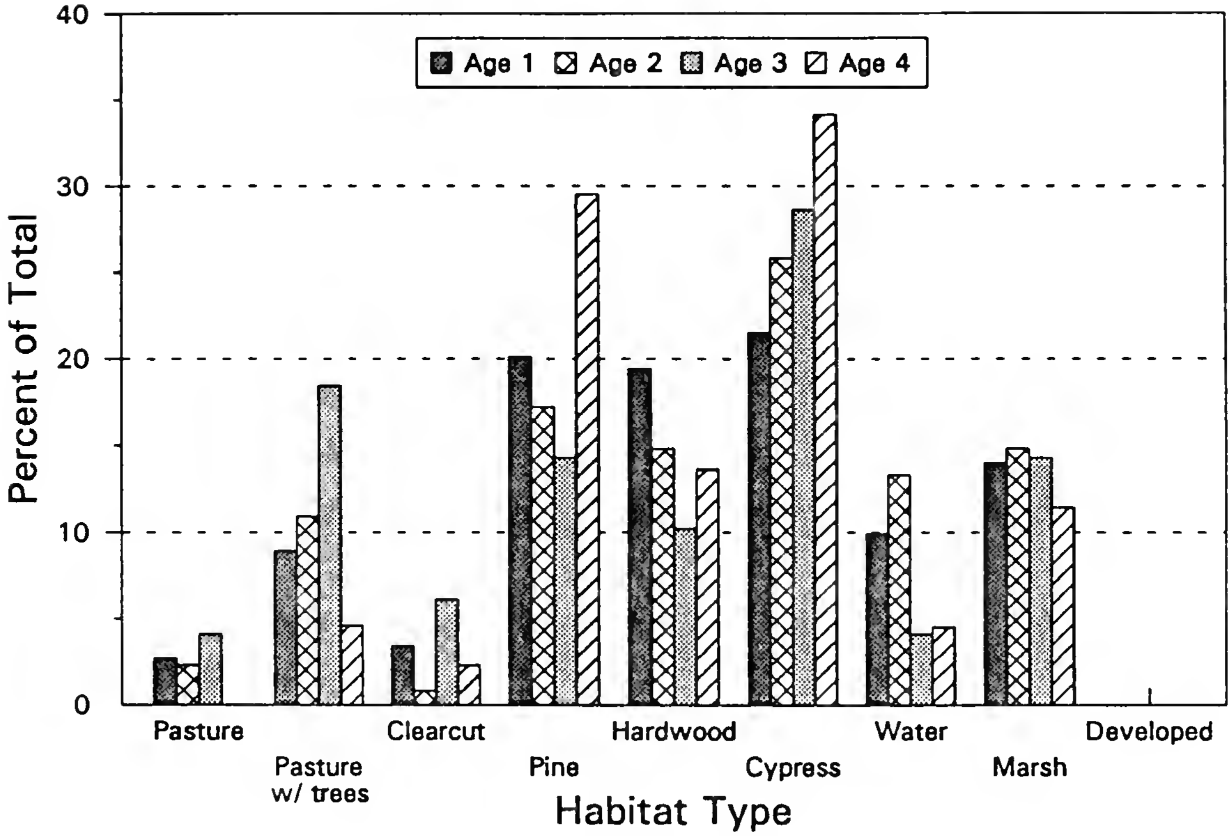

Figure 4-9. Habitat use of radio-tagged bald eagles from 1 to 4 years of age in north-central Florida, fall 1987 to spring 1991.

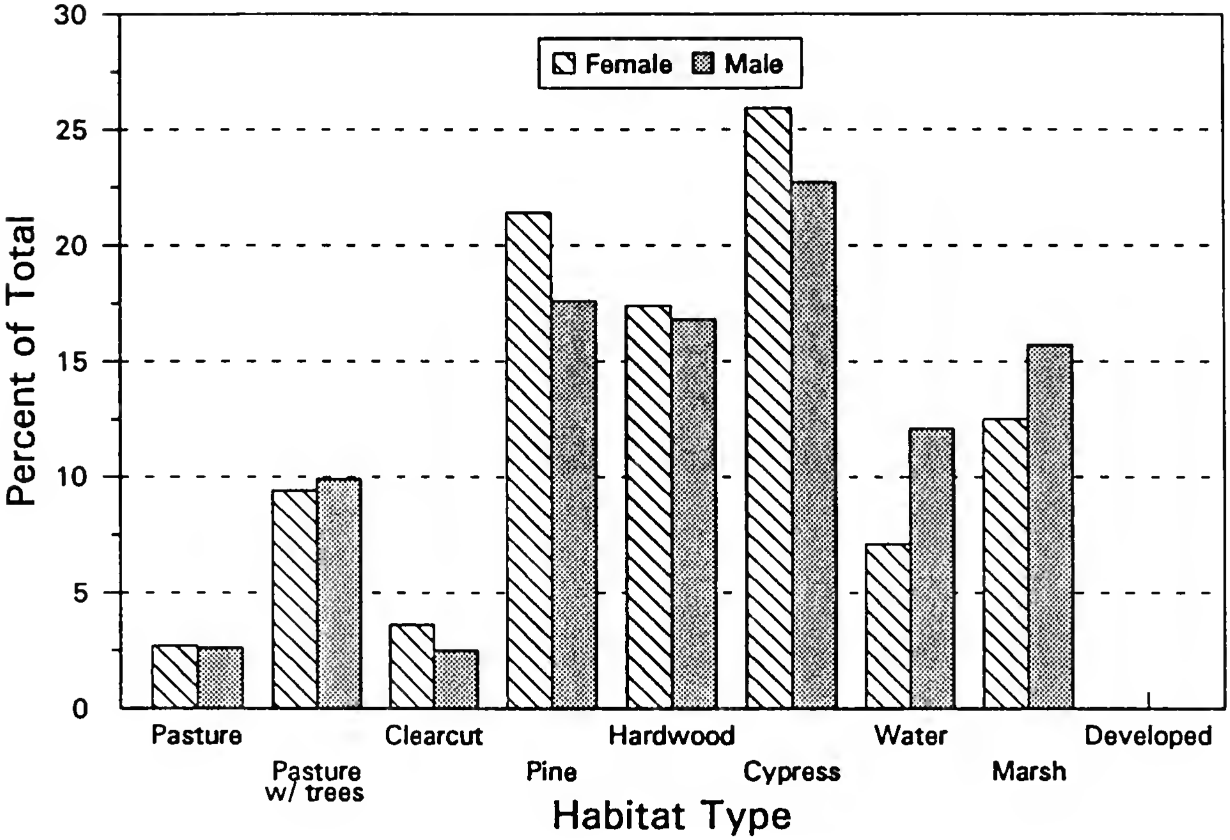

Figure 4-10. Habitat use by male and female radio-tagged bald eagles from 1 to 4 years of age in north-central Florida, fall 1987 to spring 1991.

CHAPTER 5

SURVIVAL OF SUBADULT BALD EAGLES

Introduction

Survival rates for bald eagles are poorly documented (Grier et al. 1983), yet may be the most important factor affecting growth of eagle populations (Grier 1980). Status reviews of bald eagle populations and population recovery goals generally are based on trends in reproduction and on winter counts (Sprunt et al. 1973, U.S. Fish and Wildlife Service 1989). However, population inferences based solely on productivity or age ratio data can be misleading (Grier 1979). Survival estimates for all age classes are necessary to truly assess and understand the dynamics of a population, particularly for a long-lived species that requires several years to reach breeding age. Consequently, management for bald eagles also must be aimed at all factors that influence population size including those that affect survival.

Hodges et al. (1987) reported that 8 first-year bald eagles trapped and radio-tagged on the Chilkat River, Alaska, had a known minimum 50% mortality rate. Minimum survival rates reported for marked first-year eagles include 37% (Gerrard et al. 1978) and 21% (Brown and Amadon 1968). These studies relied on reobservation of marked birds and band returns; neither method produces reliable survival estimates. Buehler et al. (1991a) reported 100% survival through the first year of life for radio-tagged eagles (n=39) on the Chesapeake Bay. Minimum survival to 3 years-of-age was 19% for wing-marked Saskatchewan eagles (Gerrard et al. 1978) compared to 56% for color-marked Maine eagles resighted at feeding stations (McCollough 1986). Eagles hacked in New York had a minimum survival rate of

22% to adulthood (Nye 1988). Only 2 of these studies (Hodges et al. 1987, Buehler et al. 1991a) calculated survival rates for individuals from a large, stable to increasing population and used radio telemetry. Both large population size and ease of relocating birds fitted with radio transmitters likely contribute to higher survival rates in these 2 studies. No gender specific survival rates have been reported for bald eagles, nor have the affects of hatch order, number of siblings, and timing of nesting been examined. No survival rates for the pre-fledging period have been reported.

In this study, I examined survival rates for radio-tagged bald eagles from 8 weeks to 4 1/2 years of age to address the following objectives:

1. Determine annual and cumulative survival rates of subadult bald eagles through 4 1/2 years of age.
2. Examine survival rates through 1 1/2 years of age in relation to sex, timing of nesting, number of siblings, hatch order, and age at dispersal.

Methods

Between 1987 and 1990, 44 8-week-old nestling eagles were fitted with radio transmitters (Chapter 2). Three did not survive to fledging age and were excluded from analyses of post-fledging survival. Of the 41 remaining, 25 were male and 16 were female (1987: 3 male, 7 female; 1988: 6 male, 4 female; 1989: 11 male, 1 female; 1990: 5 male, 4 female) (Table 2-2). While on the study area, radio-tagged eagles were tracked approximately once per week from September through June of each year. Radio-tracking procedures and transmitters are described in Chapter 2. Because eagles are highly mobile, I was not able to locate all surviving individuals during each aerial survey. Some birds regularly found on the study area left for an extended period of time, while others appeared on the study area only occasionally. Whenever possible, I visually located each bird. Locations during the

migratory period (Chapter 3) were obtained from radio-tracking reports of other researchers, sightings of patagial-marked birds, and recoveries of dead birds.

I used the Kaplan-Meier estimator (Kaplan and Meier 1958) modified to allow for staggered entry of animals into the study (Pollock et al. 1989a, 1989b) to estimate survival rates for bald eagles to 4 1/2 years-of-age. Estimated survival S(n) was calculated as

$$S(n) = [1-d(n)/r(n)]\ S(n-1)$$

where

$d(n)$ = number of deaths in time period n
$r(n)$ = number of individuals at risk during that time period
$S(n-1)$ = estimated probability of survival until the end of the previous time period

Approximate 95% confidence intervals were computed using

$$S(n) \pm 1.96 \sqrt{var[S(n)]}$$

These survival rates are the probability that a bird survives from the start of the study until the end of the nth study period. I used the log-rank test (Pollock et al. 1989a) to compare survival by sex, timing of nesting, number of chicks, and hatch order. I used logistic regression (White and Garrott 1990) to examine effects of dispersal age on survival. In each of the 4 years (1987-1990) that young were radio-tagged, eggs in 75% of all nests hatched by February 5. These were classed as normal. A nesting attempt was considered late if eggs hatched after this date. I estimated hatch order from the relative length of the eighth primary of siblings.

All individuals that disappeared were considered to have died during the month they were last located because I was unable to determine whether these birds actually died or if radio-failure occurred. Consequently, these estimates represent minimum survival rates for this subadult population. I did not calculate maximum survival rates because I had only 2 known deaths during the study. I do not believe, however, that the results of the log-rank

tests and linear regressions were biased by assuming these missing individuals had died. The probability of radio failure should be the same for all individuals.

I calculated overall survival for each year-long age class. Survival for the first year age class was calculated from the time individuals fledged until initiation of migration the following spring. At the end of the first year age class, eagles were approaching 1 1/2 years of age. Age class 2 included eagles from 1 1/2 to 2 1/2 years of age. Each successive age class followed a similar pattern. I ended survival analyses on 30 May 1991, although several individuals were known to be alive in December 1991.

Results

Of the 44 8 week old nestlings fitted with transmitters, 3 died prior to fledging. Two died at approximately 9 weeks of age; 1 died at 10 weeks of age. Survival from 8 weeks of age to fledging at approximately 11 weeks was 93.2%.

Only 2 radio-tagged eagles (both female) were known to have died during the study. Both died during the northward migration period; 1 in North Carolina 2 months after banding and 1 in New Brunswick 4 months after banding. Four banded eagles from this study also were recovered dead; 2 males near the study area in Florida 2 years and 4 years after banding, 1 male in Wisconsin 2 1/2 years after banding, and 1 female in Ontario 3 months after banding. The sex ratio for 115 banded eagles was 1.1 males per 1 female; the sex ratio of the 6 recovered eagles was 1:1. However, the sex ratio of eagles recovered in northern states was 1:3, biased towards females.

Survival was similar for radio-tagged cohorts from 1987 to 1989 (Table 5-1). The 1990 cohort had lower survival through 1 1/2 years of age. Survival was lowest in the 1 1/2 year age class (63%) and increased considerably in the older age classes beginning with eagles 2 1/2 years old (Table 5-2). Cumulative survival to 4 1/2 years of age was 50%.

I compared minimum survival curves of male and female bald eagles through 1 1/2 years-of-age; the log-rank test showed no significant difference (Table 5-3). Survival through 4 1/2 years of life also did not differ significantly by sex ($\chi^2 = 1.53$, $\underline{P} = 0.22$); females had 47.1% survival while males had 54.2% (Figure 5-1).

I also compared survival rates of young from normal and late nesting attempts and found no significant differences through 1 1/2 years-of-life (Table 5-3). Age at migration from the nest area also did not affect survival through 1 1/2 years of age ($\chi^2 = 0.001$, $\underline{P} = 0.94$).

Survival rates through 1 1/2 years of age were affected significantly by the number of young in a nest (Figure 5-2) and the order of hatch (Table 5-3, Figure 5-3). Only 49% of eagles from 1-chick nests survived, while 70% from nests with 2 chicks survived. Of eagles fledged from 2-chick nests, the older sibling had significantly greater survival (71%) than the younger sibling (59%).

Discussion

First year minimum survival rates were 63.4%, much higher than those reported by Brown and Amadon (1968), Gerrard et al. (1978) and Hodges et al. (1987). All of the known mortality and most of the lost radio signals for radio-tagged eagles occurred from April to September, the migratory period, and early in life. First year birds in Alaska migrated farther than older eagles and had greater mortality (Hodges et al. 1987). In this study, first year birds also had lower survival, but migration distance did not vary significantly by age class (Chapter 3). Consequently, when attempting to increase survival in a migratory population, management focus should be on young birds.

At northern latitudes winter starvation is the most likely mortality factor of young eagles and often occurs during migration (Sherrod et al. 1977, Stalmaster and Gessaman

1984, McCollough 1986). In Florida eagles, 4 of 6 known mortalities in this study occurred during summer migration. Three of the 4 occurred within 4 months after banding. This suggests that mortality during summer migration, particularly at younger age classes, may significantly affect overall survival of subadults and points to a need for habitat protection along migration routes and in summering areas (Chapter 3).

Two other recent studies in the eastern United States reported annual survival rates for subadult bald eagles (Table 5-4). The estimated survival for Florida eagles was the lowest, while Chesapeake Bay eagles had the greatest survival, particularly at the youngest age classes (Buehler et al. 1991a). Maine eagles showed increasing survival with age (McCollough 1986), as I found in this study, but first year survival in Maine was slightly greater. By 3 1/2 years of age, Maine and Florida populations had reached similar cumulative survival rates; the Chesapeake Bay population reached a similar survival rate by 4 1/2 years of age.

These survival estimates, particularly those for the 1 1/2 year age class, correlate well with migratory tendencies of each population. Because a long-distance migrant incurs greater energetic cost, one would predict different survival rates for populations with different migration distances. In Florida, all immature eagles migrate long distances (Chapter 3), while immature eagles remain on the Chesapeake Bay year-round (Buehler et al. 1991b). In Maine, McCollough (1986) estimated that the proportion of each cohort that dispersed during their first winter ranged from 30-60%; many winter on the Chesapeake Bay (Buehler et al. 1991b) resulting in a shorter migration distance than for Florida eagles. Thus, in the Maine and Chesapeake populations fewer individuals are exposed to the hazards of migration as young, inexperienced fliers. Greater survival in Maine also is likely the result of supplemental feeding at winter feeding areas enhancing survival (McCollough 1986), particularly of the earliest age classes.

I found no significant differences in survival rates by sex, although females had somewhat lower survival through 4 1/2 years of age. Three of 4 eagles recovered north of the study area were female, suggesting that female mortality might be higher during migration than that for males; however, sample size was small. Although no published data are available for migration distance by sex in subadult bald eagles, results from this study indicate that both males and females undergo long-distance movements and the mean maximum distance traveled was not significantly different (Chapter 3). Thus, survival rates for males and females would be expected to be similar and migration distance does not appear to be a causative factor in mortality.

Eagles fledged from 1-chick nests had lower survival through 1 1/2 years of age than those fledged from 2-chick nests. Female condition, which is affected by food abundance, influences the number of eggs laid (Newton 1979). Perhaps pairs that produce only 1 young, either by laying only 1 egg or by loss of a young chick, have a low quality nesting area. Young fledged from a low quality area may receive inadequate amounts of food, which may affect survival. In addition, fledglings with a sibling ranged significantly farther from the natal nest prior to migration than single fledglings (Chapter 2). Consequently, young from 2-chick nests had more experience flying which might have prepared them better for migration.

The first hatched chick from 2-chick nests had greater survival through 1 1/2 years of age than the second hatched chick. The older sibling generally dominated in food conflicts (Chapter 2) allowing it to energetically prepare better or more quickly for migration. Thus, the older sibling generally left the natal area first.

The 1 1/2 year survival estimate for the 1990 cohort was over 20% less than for the 3 earlier cohorts. There are 2 possible reasons for the lower survival in 1990. Florida was in the second year of a severe drought in 1990 that undoubtedly lowered prey availability and possibly reduced survival of 1 1/2 year old eagles. Alternatively and more likely, survival

may appear to be lower because some eagles had not yet returned to the study area. Since a few eagles do not return to Florida their first winter, the study may have been terminated before all surviving 1990 birds had returned.

Survival rates for immature eagles are useful for refining the statewide estimates of annual productivity. State of Florida estimates from aerial nest surveys currently are undercounting fledglings by approximately 3.6% (J. Hardesty, P. Wood, J. Smallwood, and M. Collopy, unpubl. data). Pre-fledging mortality of radio-equipped eagles was 6.8%. Use of these two figures as adjustments to the state productivity estimate results in slightly lower annual production. Annual survival rates then can be applied to a particular cohort to estimate the number of individuals expected to survive to adulthood.

Table 5-1. Survival rates through May 1991 for each cohort of radio-tagged bald eagles from 1987 to 1990, north-central Florida.

Year banded	n	Cumulative percent survival per age class 1 1/2	2 1/2	3 1/2	4 1/2
1987	10	70.0	50.0	50.0	50.0
1988	10	70.0	50.0	40.0	-
1989	12	66.7	66.7	-	-
1990	9	44.4	-	-	-
Total	41	63.4	52.9	50.0	50.0

Table 5-2. Survival rates of radio-tagged bald eagles by age class in north-central Florida, 1987 to 1991.

Age class	n	Known mortality	Lost radio signal	Percent survival	95% CI
11 wks - 1 1/2 yrs	41	2	13	63.4	51.6 - 75.1
1 1/2 - 2 1/2 yrs	26	0	4	83.5	67.3 - 99.7
2 1/2 - 3 1/2 yrs	18	0	1	94.1	83.3 - 100.0
3 1/2 - 4 1/2 yrs	6	0	0	100.0	-
Total	41	2	18	50.0	27.6 - 72.4

Table 5-3. Survival rates through 1 1/2 years of age in relation to sex, timing of hatch, number of chicks in the nest, and hatch order, north-central Florida, 1987 to 1991. N is the number at risk during the sampling period.

Variable	n	Percent survival	95% CI	$\chi^{2\,a}$	P
Sex					
Female	17	64.7	42.0 - 87.4		
Male	24	62.5	43.1 - 81.9	1.95	0.16
Timing of hatch[b]					
Normal	23	60.9	40.9 - 80.8		
Late	18	66.7	44.9 - 88.4	1.37	0.24
Number of chicks					
1	14	49.4	23.1 - 75.6		
2	27	70.4	53.1 - 87.6	4.76	0.03
Hatch order					
1	14	71.4	47.8 - 95.1		
2	13	59.1	40.5 - 77.6	8.73	0.003
Total	41	63.4	36.6 - 57.5		

[a]Log-rank test (Pollock et al. 1989a).
[b]Normal = eggs laid during first 75% of all nesting attempts; Late = last 25%.

Table 5-4. Survival rates for 3 bald eagle populations in the eastern United States.

Age class	Annual minimum survival (%)		
	Maine[a]	Chesapeake Bay[b]	This study
1 1/2	73	100	63
2 1/2	84	92	84
3 1/2	91	75	94
4 1/2	-	80	100
Cumulative to 3 1/2	56	69	50
Cumulative to 4 1/2	-	55	50

[a]McCollough 1986 [b]Buehler et al. 1991a

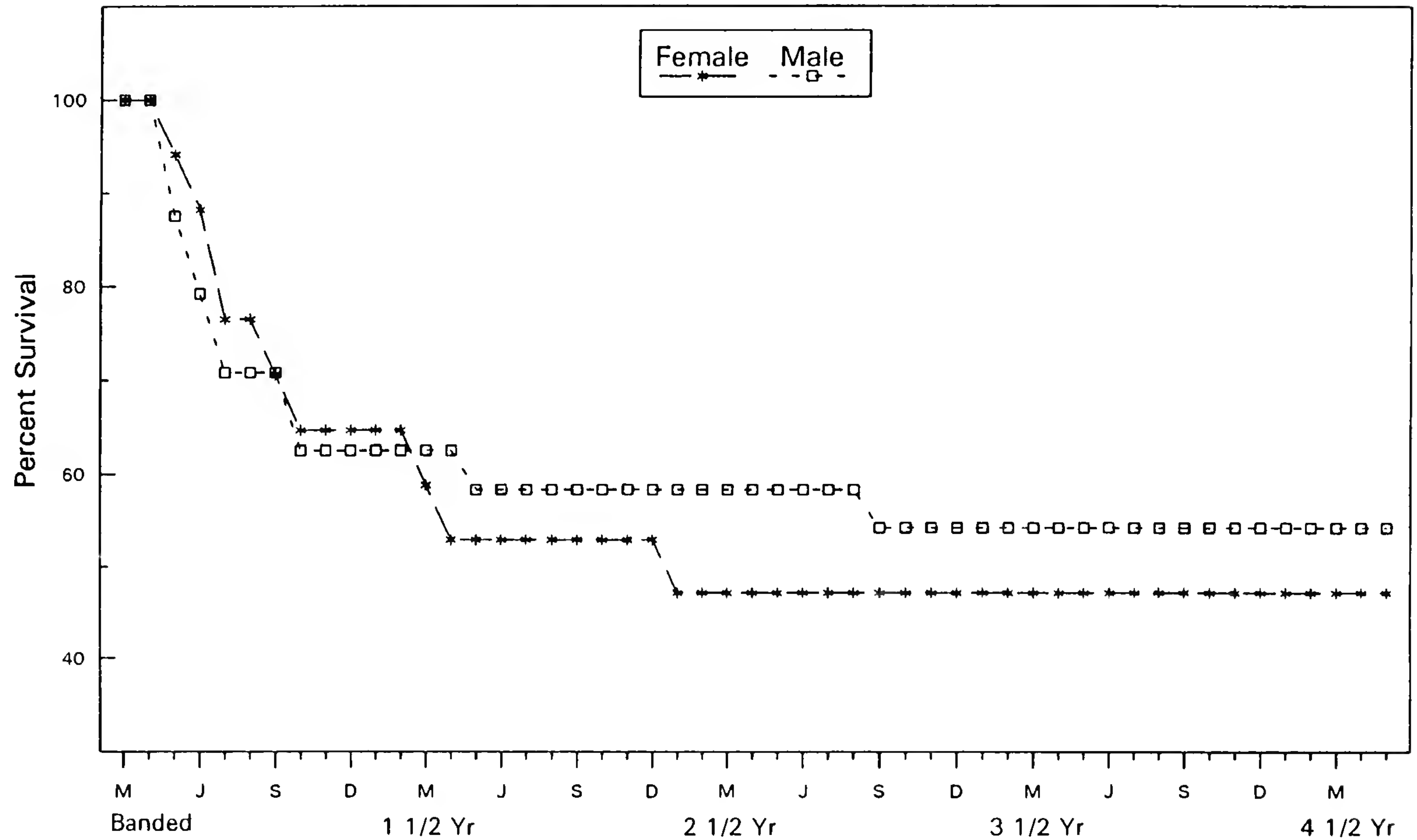

Figure 5-1. Survival curves for male and female bald eagles through 4 1/2 years of age, north-central Florida, 1987 to 1991.

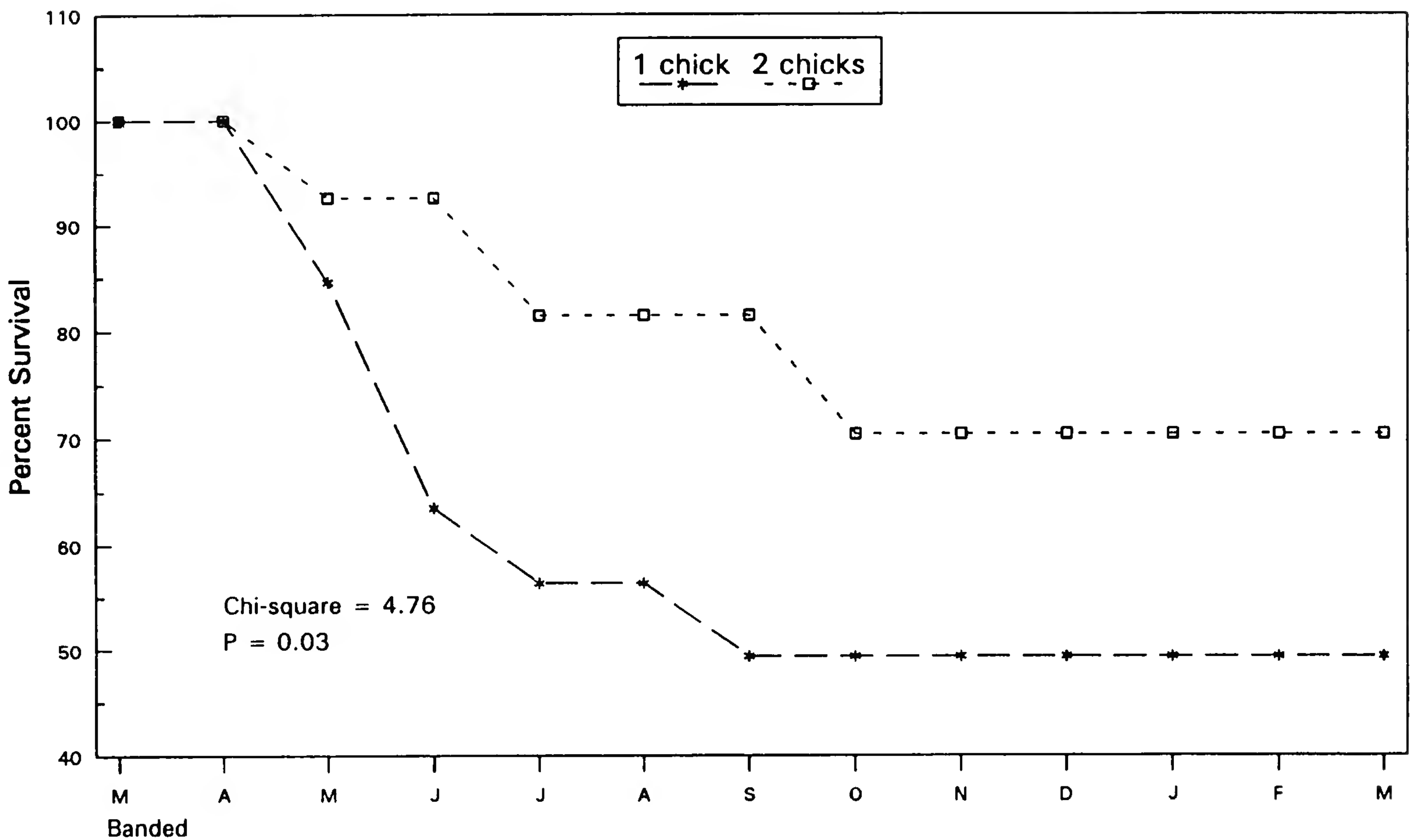

Figure 5-2. Survival curves for bald eagles fledged from nests with 1 versus 2 chicks through 1 1/2 years of age, north-central Florida, 1987 to 1991.

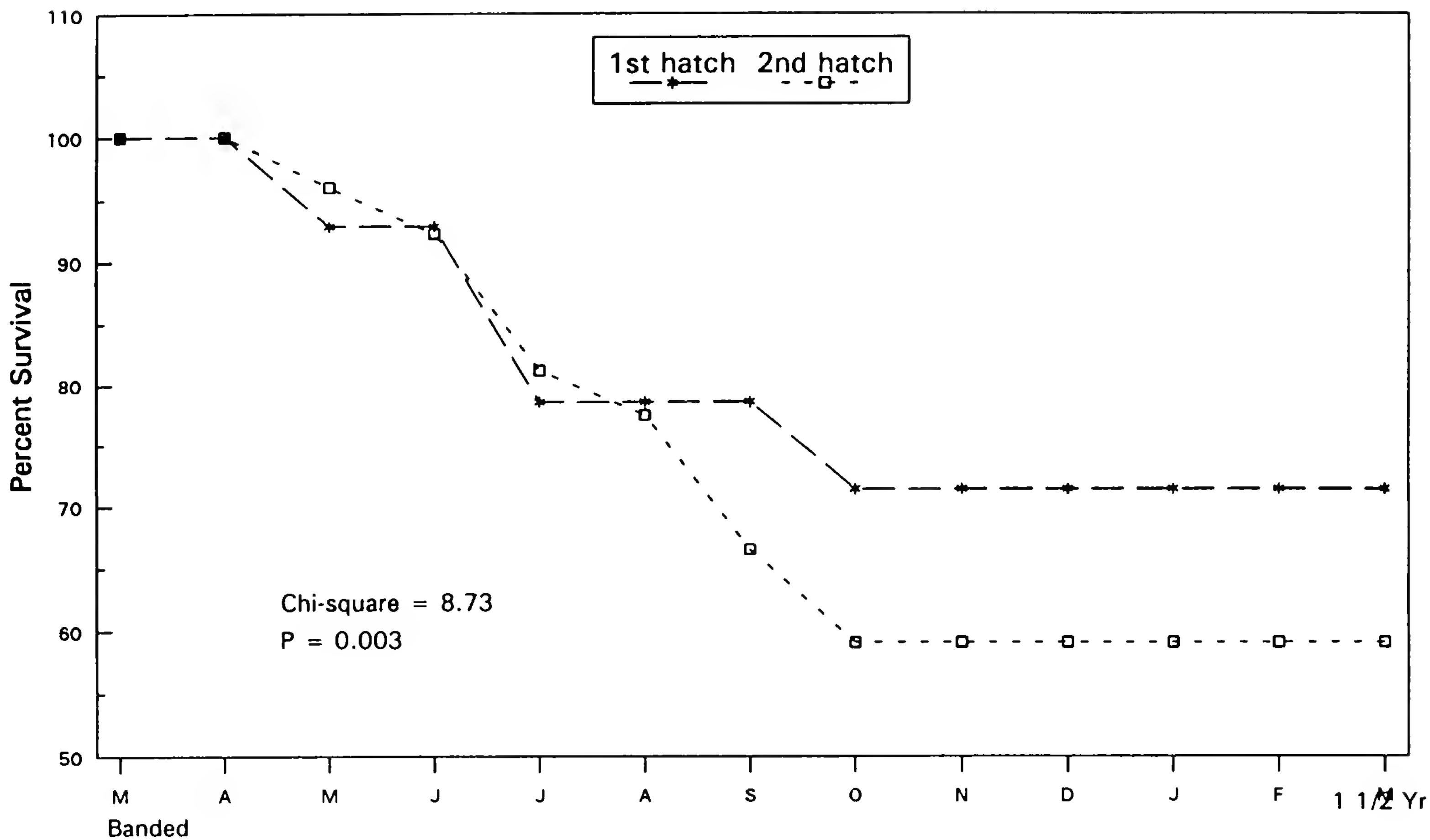

Figure 5-3. Survival curves of first and second hatched bald eagles fledged from nests with 2 chicks through 1 1/2 years of age, north-central Florida, 1987 to 1991.

CHAPTER 6

SYNTHESIS AND CONCLUSIONS

The state of Florida supports over half of the breeding population of bald eagles in the southeastern United States; 601 breeding pairs in 1991 (S. Nesbitt, pers. commun.). This represents a significant resource for the Southeast and for Florida. Currently, primary management emphasis and protection is focused on active bald eagle nest sites. No habitat protection or management activities are aimed at foraging, roosting or loafing areas for subadult eagles. In fact, habitats and habitat characteristics important to subadults had not been quantified. Because eagles do not breed until approximately 5 to 6 years of age (possibly later in Florida), a large time gap occurs in management of eagle populations. This situation is analogous to that which occurred in waterfowl research and management in the past; emphasis was on nesting areas and subadult needs were not recognized or considered (Weller and Batt 1988). This research was initiated because of the paucity of information concerning subadult bald eagle populations. I examined various aspects of subadult eagle biology that might be pertinent to survival or management of the Florida subadult eagle population.

Fledgling eagles (birds prior to their initial migration) remained dependent on adults for food and stayed at or near the natal nest until they initiated migration at an average of 7 (4-11) weeks post-fledging. Habitat protection within the 229 m (750 ft) primary protection zone used in Florida was not sufficient to meet the habitat needs of fledgling eagles because they range outside of the primary zone by 3 weeks post-fledging. Of greater importance is

the extent of the protection period. It should extend until fledglings initiate migration away from the natal area, not just until fledging. Disturbance near a nest while fledglings still are dependent on adults may cause premature dispersal of young from the nesting area prior to their attaining adequate food reserves. Fledglings in less than optimum physical condition when initiating migration may be less likely to survive the energetic demands of migration.

Survival analyses in this study indicated that greatest mortality occurred during the first summer of life after initiation of migration. Three of 4 eagles that died during migration, died within 4 months of banding. The fact that young from 1-chick nests and the younger sibling from 2-chick nests had lowest survival, also indicates that food availability during the post-fledging period can affect survival. Nests with only 1 chick probably are located in low quality territories resulting in less food available for the nestling. Bortolotti (1986) found that growth rate for 1-chick broods was slower than for 2-chick broods because of food limitations. In 2-chick nests, the older sibling generally has first access to prey delivered and will monopolize it until satiated. If prey is not abundant, the younger sibling will more likely be deprived. This also points to a need to avoid disturbance at nests during the post-fledging period to ensure that adults do not decrease prey deliveries due to excessive disturbance.

Timing of migration for fledgling eagles did not correlate well with environmental factors, but did appear to relate to food availability. Fish abundance on Newnans Lake was declining during the later stages of fledgling dependence. I observed that the first-hatched chick often dominated in food conflicts, often left the study area first, and tended to have greater survival. I suggest that young with greater food availability might migrate at a younger age because they can reach peak condition more quickly. However, additional prey availability data and experimental food provisioning studies are needed to test this hypothesis. Regardless of geographic origin, young required a minimum of approximately 4-7 weeks post-

fledging to initiate migration (Harper 1974, Kussman 1976, McCollough 1986, this study) and presumably to reach a physical condition capable of sustaining them during long distance migration.

In contrast to the initial migration of fledglings, it is doubtful that subadult (1- to 4-year-old) eagles in subsequent years migrate entirely in response to declining food availability. Earliest migration occurred when waterfowl abundance had decreased and few remained on area lakes. The extent to which subadults used this prey base is unknown. Edwards (1987) showed that fish abundance on one of the major lakes in the study area reached its peak during the time most subadults left the study area (Figure 3-4). Water levels are dropping at this time (Figure 3-1), which should make fish prey more available for a short time by concentrating the prey in a smaller area, although prey availability will decrease eventually. Increasing water temperatures (Figure 3-6) also may cause fish to move into deeper water, again decreasing prey availability. Lowest water levels, and potentially lowest prey availability occurred when the latest subadults migrated. Although fish kills generally occur on Florida lakes in August and September, they usually occur infrequently and involve low numbers of fish (J. Estes, pers. commun.). Thus, these kills are an unpredictable prey resource and occur too late in the summer to prevent subadults from migrating.

Thus, earliest migration by subadults occurred when fish abundance was at an annual high, although waterfowl abundance had declined. These early migrants doubtfully left in response to lack of prey; however, late migrants more likely left the study area in response to decreasing prey availability. Most subadults left the study area before summer air temperatures and humidity reached the annual high.

Locations of radio-tagged eagles outside of Florida ranged from South Carolina to Prince Edward Island, Canada. These data and the data of others (Gerrard et al. 1978, Buehler et al. 1991b) suggest that eagles are philopatric to summering areas, which

emphasizes the need for protection of significant summering areas. Known and assumed mortality occurred primarily during migration in northern states and primarily in the 1 1/2 year age class. Minimum survival cumulative through 4 1/2 years-of-age was 50% and did not vary by sex.

After subadults returned to the study area in the fall, individuals continued to use the same general areas each year. Temporally and locally abundant food sources on the study area resulted in temporary small concentrations of eagles. Although these isolated food sources are undoubtedly important, the portions of the study area used consistently each year by large numbers of eagles may be of greater overall importance. Management for subadult populations must include habitat protection and/or management for these concentration areas as survival of subadults may be affected if a highly used area becomes unsuitable.

Subadult eagles were not distributed randomly over the study area. Logistic regression analyses revealed that eagles tended to be located close to large water bodies and eagle nests, and were frequently in cypress and marsh habitats. Because most lakes on my study area are fringed with cypress, subadults likely preferred cypress because of its proximity to water. In other parts of Florida or the Southeast, other tree-dominated habitats near water might be preferred. Structural height diversity appeared important to subadults; 73% of perch locations occurred on the edge of the canopy or in the supercanopy. They avoided main roads and developed areas. Although subadults often frequented areas near eagle nests, they wandered over large areas. Thus, habitat protection in the 229 m zone around eagle nests falls short of the habitat needs of subadults. Habitat management and protection measures must be aimed at areas that exhibit the habitat characteristics preferred by subadult eagles and that act as important loafing and foraging sites for subadult eagles. As human populations and lakeshore developments continue to increase, protected areas will become increasingly important to the subadult population.

In summary, I suggest that primary management emphasis should occur during the post-fledging period. Fledglings remain tied to the nest at this time--a discrete area that can be delineated. Because greatest mortality occurs during the first year of life, primarily after initiation of migration, management and protection of larger areas around nest sites, restricting disturbance until fledglings migrate, and protection of associated foraging areas for adults during the post-fledging period might increase survival chances during the first year. This, in conjunction with management and protection of areas where subadult eagles congregate, will become increasingly necessary as the human population of Florida continues to grow and alter more of the natural landscape. As Grier (1980) showed with population modeling, eagle populations are twice as sensitive to subadult survival than productivity. Therefore, protection of areas heavily used by subadults is essential.

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APPENDIX

BANDING DATA

Appendix. Banding data (1987-1991) for nestling bald eagles in north-central Florida.

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
870311	AL39	629-16701	RW-A11	-	27.7	123	206		M		2/4/91 FL
870311	AL17	629-16702	RW-A12	-	31.1	136	213		F		
870311	AL17	629-16703	RW-A13	-	28.9	136	178		F		
870313	PU8	629-16705	RB-A01	-	24.5	120	98		U	6.0	
870313	PU8	629-16706	RB-A02	-	24.8	112	22		U	6.0	
870401	AL27	629-16707	RW-A14	165.675	30.7	109+[a]	222		F	8.0	
870403	AL19	629-16708	RW-A15	165.999	32.4	117+	268		F	8.0	8/30/87 NB
870403	AL19	629-16709	RW-A16	-	30.4	138	247		F	8.0	
870403	MR108	629-16710	RW-A17	165.861	31.6	128	274		F	8.0	
870403	MR108	629-16711	RW-A18	-	29.4		230		F	8.0	
870406	AL32	629-16712	RW-A19	-	27.9	116	241		M	8.0	
870406	AL32	629-26207	ALAB	-	29.5		232		U	8.0	
870406	AL15A	629-16713	RW-A20	-	31.2		272		F	8.0	
870406	AL15A	629-26208	ALAB	-	27.5	108	195		M	8.0	
870406	AL17C	629-16714	RW-A21	165.881	33.3	124	227		F	8.0	
870406	AL17C	629-26211	ALAB	-	30.7		207		F	8.0	
870406	AL24A	629-16715	RW-A22	-	31.4		250		F	8.5	
870406	AL24A	629-26212	ALAB	-	31.0		220		F	8.5	
870407	PU18	629-16716	RB-A03	-	26.0	105	93		M	6.5	9/4/89 WI
870407	PU18	629-26213	ALAB	-	26.4	111	171		M	7.0	
870407	MR105	629-16717	RB-A04	-	31.5	122	250		F	8.5	
870407	V034	629-16718	RB-A05	-	29.9	114	252		M	8.5	4/16/89 FL
870407	V034	629-16719	RB-A06	-	30.6	117			M	8.5	
870408	AL35	629-16720	RW-A23	165.942	31.1	125	248		F	8.5	

Appendix (cont.)

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
870408	AL35	629-16721	RW-A24	165.718	31.2	133	272		F	8.5	
870424	PU115A	629-16722	RB-A07	-	28.4	121	185		M	7.5	
870424	PU115A	629-16723	RB-A08	-	27.5	121	211		M	7.5	
870424	PU118	629-16724	RB-A09	-	32.4	124	177		F		
870424	MR9	629-16725	RB-A10	-	28.6	121	187		M	8.0	
870502	LV25	629-16726	RW-A25	165.520	28.4	116	229		M	8.0	
870502	LV25	629-16727	RW-A26	-	28.7	122	253		M	8.0	
870502	AL7A	629-16728	RW-A27	165.616	29.2	122	179		M	7.0	
870502	AL7A	629-16729	RW-A28	165.100	27.7	125	201		M	7.0	
870503	AL33	629-16730	RW-A29	165.958	32.6	134	174		F	7.5	7/7/87 NC
880311	AL32A	629-16731	01	165.957	28.6	127	268		M	9.0	
880311	AL32A	629-16732	02	165.998	30.8	136	281		F	9.0	
880319	AL15A	629-16733	03	165.081	27.6	129	228		M	7.5	
880326	MR3	629-16734	04	-	29.9	132	162		F	7.0	
880326	MR3	629-16735	05	-	30.9	134	178		F	7.0	
880326	MR3	629-16736	06	-	26.8	126	182		M	7.0	
880326	MR105	629-16737	07	-	28.5	121	241		M	8.0	
880326	MR105	629-16738	08	-	28.2	124	255		M	8.0	
880407	AL10	629-16739	09	165.145	30.1	133	177		F	7.0	
880407	VO30		ALAB	-	30.9	133	171		F	7.5	
880407	VO30	629-16741	10	-	29.0	124	204		M	7.5	
880407	PU8A	629-16742		-	30.2	124	166		M	7.0	
880407	PU8A		ALAB	-	30.7	132	182		F	7.0	
880420	MR107	629-16743	11	165.155	31.8	127	273		F	9.0	

Appendix (cont.)

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
880421	AL17B	629-16744	12	165.180	32.1	131	245		F	8.5	
880422	AL14	629-16745	13	165.212	31.2	127	263		F	8.5	
880425	AL40	629-16746	14	165.262	27.9	120	265		M	9.0	
880425	AL40	629-16747	15	165.241	27.9	123	248		M	9.0	
880428	VO39	629-16748	16	-	31.8	134	231		F		
880428	VO39	629-26221	ALAB	-	29.2	122	213		M		
880428	VO29A	629-16749	17	-	29.9	124	235		M		
880428	VO29A	629-26222	ALAB	-	31.7	134	245		F		
880428	PU115A	629-16750	18	-	29.0	125	224		M		
880428	PU115A	629-26223	ALAB	-	31.4	132	224		F		
880428	AL24A	629-16901	19	165.418	29.0	119	234		M	7.5	
880428	AL24A	629-16902	20	165.561	30.3	130	217		F	7.5	
880501	AL33	629-16903	21	165.593	28.7	122	241		M	8.0	
890304	AL17A	629-16905	22	165.755	28.1	115	261	3.6	M	8.0	
890304	AL17A	629-16906	23	165.698	28.2	115	271	3.2	M	8.0	
890304	AL53	629-16907	25	-	31.0	141	228	4.2	F	7.0	
890304	AL53	629-16908	26	-	31.2	132	206	3.6	F	7.0	
890218	ADULT	629-16904	31	-	33.0	F					
890312	AL3B	629-16909	24	165.933	28.7	125	210	3.4	M	7.5	
890312	AL3B	629-16910	27	165.210	28.2	117	225	3.5	M	7.5	
890318	AL28C	629-16911	28	164.399	30.1	134	325	4.0	F	9.0	
890318	AL28C	629-16912	29	164.798	27.8	123	322	3.4	M	9.0	
890326	AL24A	629-16913	30	164.897	27.7	116	232	2.3	M	8.0	
890326	AL26A	629-16914	32	164.756	28.3	128	220	3.6	M	8.0	

Appendix (cont.)

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
890329	AL40	629-16915	33	164.814	28.1	124	205	3.2	M	8.0	
890329	AL40	629-16916	34	164.738	28.5	125	234	3.0	M	8.0	
890329	AL10	629-16917	35	164.496	28.9	120	250	3.1	M	8.0	
890330	MI28	629-16918	1	164.549	31.1	130	296	4.3	F	9.0	
890330	BR2	629-16919	2	164.089	31.4	141	257	4.3	F	8.0	
890403	LA42A	629-16920		-		115	265	3.4	M	8.5	
890404	MR121	629-16921	36	-	31.1	201		3.9	F	8.0	
890405	AL33	629-16922	37	164.197	29.9	122	282	3.4	M	9.0	
890417	AL1A	629-16923	38	164.895	29.0	128	200	3.1	M	8.0	
890422	MIVO3	629-16924	3	165.950	28.4	128	229	3.3	M	7.0	
890408	PU8A	629-16926	41	-			305		U	9.0	
890408	PU8A	629-16927	42	-			338		U	9.0	
890408	PU10A	629-16928	43	-			293		U	8.0	
890408	PU10A	629-16929	44	-			265		U	8.0	
890409	PU20	629-16930	45	-		122	315		M	10	
890409	PU22A	629-16931		-		135	142		F	6.5	
890409	PU22A	629-16932	46	-		136	155		F	6.5	
900304	MR111C	629-16933	50	-	28.1	121	250	3.1	M	8.0	
900304	MR108	629-16934	51	-	29.1	123	278	3.2	M	8.7	
900304	AL19	629-16936	52	-	31.6	131	330	3.8	F	9.0	
900304	AL52	629-16937	53	-	27.5	122	205	2.6	M	7.0	
900304	AL52	629-16935		-	26.5	121	140	2.4	M	6.5	
900316	AL50	629-16938	55	-	28.1	123	288	3.0	M	8.5	
900316	AL50	629-16939	56	164.011	28.4	120	247	2.5	M	8.0	

Appendix (cont.)

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
900316	AL32A	629-16940	57	164.033	26.8	123	228	2.7	M	7.5	
900316	AL32A	629-16941	58	164.902	29.4	129	260	3.1	M	8.0	
900316	AL3B	629-16942	59	165.570	28.7	120	266	3.4	M	8.5	
900316	AL3B	629-16943	60	165.580	28.0	104	265	3.0	M	8.5	
900322	AL43	629-16944	54	-	27.6	122	163	3.0	M	7.0	
900322	AL43	629-16945	61	164.963	31.2	129	242	3.9	F	7.5	
900325	MR120	629-16946	62	-	28.0	123	293	3.1	M	8.5	
900325	MR120	629-16947	63	-	26.9	122	265	3.0	M	8.5	
900325	V029	629-16948	64	-	31.1	128	270	3.7	F	8.5	
900325	VO29	629-16949	65	-	32.1	127	213	3.8	F	8.5	
900406	MR57	629-16950	66	-	30.6	132	204	3.7	F	8.0	7/19/90 Ontario
900406	MR57	629-16951	67	-	29.0	122	216	2.9	M	8.0	
900406	MR121	629-16952	68	-	27.1	120	204	2.9	M	8.0	
900414	AL26A	629-16953	69	164.666	32.1	134	252	4.1	F	8.5	
900414	AL1A	629-16956	70	165.992	30.7	129	238	3.6	F	8.0	
900506	AL29A	629-16957	71	-	26.5	121	173	2.6	M	7.0	
900506	AL29A	629-16958	74	164.969	30.4	138	201	3.7	F	7.5	
900224	MI32	629-16925		165.112	29.4	124	276	3.5	U	8.5	
900407	MI27	629-16954		164.610	28.3	123	300		U	8.0	
900407	MI27	629-16955		165.392	30.5	131	270	4.1	U	7.5	
910216	MR109A	629-16960	12	-	29.8	121	237	3.3	M	8.0	
910216	MR109A	629-16961	13	-	31.2	138	257	4.0	F	8.0	
910216	MR108	629-16962	30	-	30.0	137	123	4.1	F	8.0	
910216	AL45	629-16963	39	-	30.1	123	288	3.3	M	9.0	

Appendix (cont.)

Date banded	Nest number	Band number	Tag number	Radio frequency (mhz)	Bill depth (mm)	Foot pad (mm)	Eighth primary (mm)	Weight (kg)	Sex	Age (wks)	Date Recovered/ Location
910216	AL45	629-16964	40	-	30.4	137	260	4.2	F	9.0	
910217	AL15A	629-16965	47	-	30.5	136	282	4.2	F	9.0	
910301	MR115	629-16966	48	-	32.2	136	278	4.4	F	9.0	
910301	MR115	629-16967	49	-	32.3	141	306	4.5	F	9.0	
910301	MR114A	629-16968	50	-	28.1	123	256	3.2	M	8.0	
910301	MR114A	629-16969	67	-	30.4	129	244	3.8	F	8.5	
910308	AL19	629-16970	72	-	30.2	136	287	4.2	F	8.5	
910308	AL19	629-16971	73	-	31.8	135	286	4.0	F	8.5	
910309	AL32A	629-16972	75	-	27.4	124	208	2.9	M	7.5	
910309	AL32A	629-16973	76	-	31.8	138	233	3.8	F	8.0	
910309	AL43	629-16974	77	-	32.2	141	198	3.9	F	7.5	
910328	AL17F	629-16975	79	-	28.1	120	248	3.1	M	8.5	
910328	AL17F	629-16976	80	-	31.3	137	242	3.9	F	8.5	
910328	AL17D	629-16977	78	-	29.5	140	179	3.8	F	7.5	
910328	AL17D	629-16978	81	-	32.2	140	213	4.2	F	7.5	
910329	AL52	629-16979	82	-	27.8	125	184	2.9	M	8.0	
910330	AL42	629-16980	83	-	30.8	132	202	3.8	F	7.5	
910330	AL42	629-16981	84	-	30.0	132	187	3.6	F	7.5	

[a]Foot pad not fully extended.

BIOGRAPHICAL SKETCH

Petra Bohall Wood was born on 10 March 1959 in Bad Windsheim, West Germany. She emmigrated to the United States in 1966 with her family and grew up in a small town in southern Indiana. Petra enrolled at Purdue University, West Lafayette, Indiana, in fall 1977 and completed her Bachelor of Science degree in wildlife management in May 1981. In August 1981, Petra continued her studies at the University of Florida and completed the requirements for the Master of Science degree in wildlife ecology in April 1984 (a very good year--she also married John Wood and began work at Archbold Biological Station). Her master's thesis is entitled "Habitat selection, seasonal abundance, and foraging ecology of American kestrel subspecies in North Florida." Before enrolling at the University of Florida in fall 1987 to pursue her doctorate working on subadult bald eagles in north Florida, Petra assisted with research on wading birds, worked at Archbold Biological Station primarily on small mammals and herptiles, and worked as a biologist at the University of Florida from 1985 to 1987 conducting research on effects of egg removal on eagles and characterizing eagle nesting habitat with Dr. Michael Collopy. Petra completed her PhD degree in spring 1992. She accepted a position beginning July 1992 of Assistant Unit Leader--Wildlife at the West Virginia Cooperative Fish and Wildlife Research Unit, USFWS, and Adjunct Assistant Professor at West Virginia University.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosphy.

Michael W. Collopy
Michael W. Collopy, Chairman
Professor of Forest Resources
and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosphy.

John H. Kaufman
John Kaufman
Professor of Zoology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosphy.

H. Franklin Percival
H. Franklin Percival
Associate Professor of Forest
Resources and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosphy.

Joseph M. Schaefer
Assistant Professor of Forest
Resources and Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosphy.

Melvin E. Sunquist
Melvin E. Sunquist
Associate Scientist of Forest
Resources and Conservation

This dissertation was submitted to the Graduate Faculty of the School of Forest Resources and Conservation in the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 1992

Director, Forest Resources and Conservation

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